THE SCIENTIFIC MONTHLY

THE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

VOLUME XVII
JULY TO DECEMBER, 1923

NEW YORK
THE SCIENCE PRESS
1923

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA

THE SCIENTIFIC MONTHLY

JULY, 1923

THE DEBT OF SCIENCE TO PASTEUR

By Professor GARY N. CALKINS
COLUMBIA UNIVERSITY

It is hardly possible to put in a few words an adequate expression of the debt of science to Pasteur! A consummate master of the method of science; not a medical man, yet by his achievements establishing medicine in all its branches on a scientific foundation; not a biologist, yet by sheer force of scientific method able to shape and to securely place the keystone in the arch of our conceptions of living nature. And what a model for all men was his tolerance of the shabby quarters in the garret of the Écolé Normale in the Rue d'Ulm! Here, surely, he demonstrated the fact that achievement is not the reflected radiance of a palace of research, but comes from within.

"Wherever he went," says Duclaux, "Pasteur was an initiator. Guided by an imagination so adventurous and at the same time so well controlled, we are constantly on the borders of new countries, but we journey in security." All of these countries are in the territory of biology and it is difficult to draw the line between those which are strictly biological in a modern sense, those which are chemical, and those which are strictly medical. His mind worked progressively, always building a new edifice on the foundation of a principle which he had previously demonstrated. We irresistibly look back of his final achievements in preventive medicine, to his earlier work on chicken cholera and splenic fever and from this, still back to that inspiration, the germ theory of disease, which grew up with his investigations on the cause and prevention of silkworm epidemics. Here, again, a great truth was but crystallization in a mind saturated with conceptions of the varied activities of minute organisms responsible, as he had shown, for the multiple phenomena of fermentation. And who shall say that the explanation of these phenomena was not the outcome of his first

work in chemistry on the rotary power of crystals and molecular asymmetry?

Most of Pasteur's great discoveries were the results of investigations undertaken in response to economic or human needs. So it was with fermentation. In 1856 a Lille manufacturer, having difficulty in the making of beet root alcohol, came to Pasteur for advice, and the latter consented to make some experiments. As a result of these experiments a new road was opened, one road which was to lead him to some of the most important discoveries in the history of science.

Ideas on fermentation at this time were confused and highly speculative, even those of a master as great as Liebig were little in advance of the shrewd guesses of the 17th century. The atomic theories of Descartes had already found their way into chemistry when Willis, and later, Stahl in the latter part of the 17th century, adopted them in the explanation of alcoholic fermentation. "Every substance," said Stahl, "in a state of putrefaction easily transmits this state to another body still free from decay. Thus it is that a similar body, animated already by an internal movement, may, with the greatest facility, involve in the same internal movement another body still in repose but disposed by nature to a similar movement."

This mystical conception, supported by many of the great chemists of the last century—Lavoisier, Gay Lussac, Berzelius, Liebig—became firmly established. Lavoisier, infatuated with oxidation, paved the way for Gay Lussac to see in it the chief agent in fermentation, although, indeed, the latter, and Lavoisier before him, had found it necessary to add a little of that corpuscular substance which Leeuwenhoek had discovered in 1680 and which had become known as yeast.

Leeuwenhoek, himself, suspected that the corpuscles in yeast were living organisms, a suspicion confirmed and proved by observations and experiments by Helmholtz, Schwann, Kützing and Cagniard-Latour in the first half of the 19th century.

The part played by the living yeast corpuscles formed the crucial problem when Pasteur entered the lists. To him Liebig's conception of fermentation was particularly repugnant. This great chemist while admitting the organic nature of yeast, held that fermentation is due to extremely alterable substances which easily decompose. The molecular activity brought about by this decomposition sets in motion the molecules of the fermentable matter. Yeast, when dead, forms such an alterable substance and imparts its disintegrating activity to the fermentable sugar.

Liebig's purely dynamic conception was everywhere accepted and taught, and was applied not only to alcoholic fermentation,

but to all decomposition and putrefaction. Why, it was asked, should alcoholic fermentation be dependent upon yeast if other types of fermentation occur when no yeast is present?

Pasteur's solution of the problem is typical. He struck first at the widely accepted view that fermentations are due to unknown molecular forces. He demonstrated experimentally—first with lactic fermentation, that different kinds of activities of similar nature are brought about through the vital activities of living organisms, and he showed that each type is dependent upon its own specific kind of microorganism. In the case of alcoholic fermentation it has become part of the routine in every biological laboratory to perform his crucial experiment of growing pure yeast in water containing sugar, ammonium tartrate and mineral salts of calcium-phosphorus, magnesium, etc., but with no trace of organic nitrogen. Here the yeast does not die and disintegrate as Liebig's theory requires. On the contrary it lives and multiplies vigorously at the expense of the sugar. Alcohol, carbon dioxide, glycerine and succinic acid are left after the yeast takes what it needs as food from the sugar.

Pasteur was not content to rest with this demonstration. His clear-thinking mind reached beyond the horizon of fermentations to the intricate play of living things whereby the equilibrium of nature is maintained. He saw the part played by microorganisms in putrefaction and decomposition; he saw how, through their activities, the protein matter and all substances composing the bodies of animals and plants are ultimately reduced to ammonia, carbon dioxide, mineral salts and water and restored to the earth. Here, taken up by green plants, they are brought back again through photosynthesis to the realm of living protoplasm. He thus added the physical basis of life to Helmholtz's principle of the conservation of energy and gave to general biology, for the first time, a realizing sense of the marvelous cycle of matter and energy in living nature.

His studies on fermentation opened up a new series of problems. On every side arose the inevitable question: Whence come these minute living organisms? Do they develop spontaneously or do they come from pre-existing organisms like themselves?

In all ages, spontaneous generation has been the refuge of the uninformed and the hopelessly ignorant. Even as late as the 17th century, eels, salamanders, lizards, flies, bees, etc., were regarded as originating by spontaneous generation, and we find a noted chemist of that day gravely handing down to us an infallible recipe for making mice: "Place a piece of soiled linen in a vessel; add a few grains of corn; and in twenty-one days the mice will be there, fully adult, and of both sexes."

Such views strike us as too silly for belief. But in those days tradition and superstition were powerful factors which few dared to question. Redi, and later Vallisneri, both Italian physicians, were among the first to doubt and to follow up their doubts with experiments. The former proved that flies would not develop from rotting meat if the latter is properly covered by gauze. He noted that flies, attracted no doubt by the odor of the meat, deposit eggs on the gauze. He saw that larvae develop from the eggs, and flies from the larvae Vallisneri proved that the worm-like grub found in fruit does not develop from the fruit, but from an egg deposited there by an insect. Little by little the old traditions were replaced by facts, and so far as these larger animals are concerned, the theory of spontaneous generation was abandoned

In 1675, however, the world of microscopic life was opened up by the Dutch naturalist Leeuwenhoek. Minute living things were found to develop in pure rain water, as well as in all moisture where organic matter was present. How could their origin be explained save through spontaneous generation? The old tradition, reinforced, came back, and experiments analogous to those of Redi and Vallisneri in the hands of Buffon, Needham, Pouchet, Joly, Bastian and others appeared to verify it. Other experiments, with conclusions opposed to spontaneous generation, by Spallanzani, Schultze, Schwann and others were incomplete and failed to carry conviction. The idea that specific living germs are present in the air was inconceivable, and partisans of spontaneous generation certainly had the best of it in argument. "We are mindful," they would say, "of a certain experiment of Gay Lussac where a small amount of the must of grapes when brought in contact with a few bubbles of air would begin to ferment. You say these bubbles brought with them some germs of yeast, but they must bring something else. How could a bubble of air bring germs of yeast into one fluid, something else into an infusion of hay, and still other things into meat infusion? That makes a great many germs," and, Pouchet added, "the air thus peopled would have the density of iron."

Prepared by his previous experience with fermentations, Pasteur was ready. With infinite patience experiments were planned and carried out. Nutrient, but sterile media in sealed flasks, exposed to heated or filtered air, in the great majority of cases remained sterile; so, too, when exposed to rarefied mountain air.

From his discussions with Pouchet and Joly there followed the conclusive proof that germs are present in the air we breathe; from his discussions with Bastian, who remained a heterogenist until his death a few years ago, came the proof that solids and liquids, as well as the air, are carriers of germs. It was from these discus-

sions, particularly from those with Bastian, that the modern technique in bacteriology and in surgery has been developed, although not by Pasteur alone.

The ghost of spontaneous generation, however, was not yet laid. Notwithstanding the fact that the media used by Pasteur were apparently sterile and the air supplied was germ-free, an active development of micro-organisms occurred now and then. Such exceptions were eagerly seized by his opponents as evidence that in these flasks only were the proper conditions for spontaneous generation provided. Pasteur's experience had not brought to light the fact that the spores of some organisms, e g, *Bacillus subtilis*, have the power to resist prolonged heating at high temperatures which kill actively living germs. This fact was later demonstrated for the first time by Jeffries Wyman. Such heat-resistant germs were the cause of fermentation in Gay Lussac's must of grapes; they developed in Pouchet's sterilized hay infusion, and they were present in Bastian's samples. Gay Lussac affirmed the phenomenon to be due to oxygen; Pouchet and Bastian to spontaneous generation, Pasteur to germs of the air. All were mistaken. Later it was shown that the heat-resisting spores develop only in the presence of atmospheric air. Pasteur was right so far as the presence of a germ is concerned; Gay Lussac was right so far as the need of oxygen was concerned; Pouchet and Bastian were hopelessly wrong, and the theory of spontaneous generation has not since been revived.

Pasteur was by no means satisfied with his incomplete demonstration that, like higher types of organisms. all types of germs are derived from germs similar to themselves. He was planning further extensive experiments in this direction when he was called upon to undertake a new and an entirely different kind of work. The great silk industry of southern France, already vastly reduced, was threatened with complete ruin by a deadly epidemic amongst the silkworms. In Italy, Spain, Austria, Greece, Turkey and even in China, the conditions were the same. In Japan only were there healthy moths. Pasteur was asked to investigate the disease and, if possible, to find a remedy.

This is the point in Pasteur's career where, if at all, we can draw the line between his foundations and his later triumphs, between his achievements in general biology, and those in preventive medicine. During the six years which he devoted to the silkworm problem, there gradually developed in his mind the conviction that many human diseases, like the silkworm disease, are due to microorganisms. Duclaux writes of this period: " . . . Nothing can be more curious than to see Pasteur at close quarters with a bristling, complicated problem, beginning by being deceived about it,

by seeing things the wrong side to, but led back continuously to the truth by experiment, and ending by unravelling all the complications. I do not know a more beautiful example of scientific investigation. It is the first camp on a route wherein he found immortality; the earlier discoveries had given him only glory."

The silkworm disease was not new and considerable information had accumulated in regard to it. The body wall of infected worms is covered with small black spots, giving it a peppered appearance This had led de Quatrefages to name the disease pebrine. Tissues and organs of such insects had also been found to be riddled by curious, minute corpuscles which were first seen in 1849. Some investigators looked upon these corpuscles as definite living causes of the disease, which Naegeli 1857 named *Nosema bombyces;* others interpreted them as normal products of all moths. Six years before Pasteur began his work Osimo and Vittadini, Italian sericulturists, had recommended that all eggs showing corpuscles on microscopical examination should be discarded. Their advice was regarded as fantastic and unnecessary, particularly after Cantoni and Balotti in 1863 had obtained infected moths from eggs without corpuscles and had concluded that microscopical examination was as worthless as all other remedies.

All of this was unknown to Pasteur when he went to Alais in 1865. From the available literature, he believed at once that the key to the problem lay in the famous corpuscles. He looked for them and found them in abundance. Beginning his experiments a little at random he soon made an important observation Of two broods of silkworms which he was studying, one was a fine, healthy lot which had finished its larval life and had ascended the heather to spin cocoons. The other brood had dragged along and looked badly; the worms were drooping, ate little, and the harvest of cocoons was a failure. On microscopic examination he found that the fine, healthy worms were riddled with the corpuscles, while the more degenerate lot showed few or none. Investigation showed him that the phenomenon was widely spread in the region about Alais.

Here at the outset was a blow to the view that the corpuscles had a causal relation to the disease. Its effect was so lasting that for two years Pasteur was thrown off the track. He drew the conclusion that of the two broods, both had the same disease, but the stronger lot had contracted it later in life and had sufficient vigor to form cocoons and moths, while the weaker lot had acquired the disease earlier and had succumbed before the chrysalis stage. This result led him to believe that the corpuscles were not the cause of the disease but were characteristic degeneration products of the tissues, and formed as a result of the disease. It is interesting that the practical application of this false idea was as successful as

though a true interpretation had been found. He advocated and practiced the selection of non-corpuscular eggs from moths likewise free from them. Their absence from such material would indicate that the disease was at least not advanced and would ensure a successful crop of cocoons. He thus returned to the method advised by Osimo.

With eggs thus free from corpuscles, and with eggs and larvae containing the corpuscles, he had material necessary for the experimental method of research. Batches of eggs from infected and non-infected lots were grown under identical conditions; corpuscles were always abundant in larvae and moths from eggs which contained corpuscles, and in many cases from eggs free from corpuscles, but always a good proportion of healthy insects came from the latter group. He also found that by feeding healthy larvae with food containing corpuscles, the tissues and organs of the moths which developed were loaded with them. This would seem to be pretty conclusive evidence that pebrine is due to the corpuscles, but with singular obstinacy he still clung to the view that corpuscles are effects, not causes of the disease. As one of his biographers has said: "He had, until the end of two years, marched directly towards the promised land, but he had marched backwards. As soon as he turned about the whole of his conquest appeared to him at once." He made this turn in 1867. Improvements in technique gave him healthy broods entirely free from corpuscles. He inoculated some of these through the body wall as well as through the mouth with contaminated food. He allowed infected larvae to inoculate healthy ones through lacerations made by claws, and in all cases pebrine followed. The evidence became irresistible and long after his assistants and collaborators were convinced, he himself was forced to see in the corpuscle the cause of pebrine. But how account for the fact that many worms died without showing any trace of the corpuscles, as was the case in his earlier observations? How account for the fact that some of his own healthy eggs in the hands of less experienced culturists gave rise to diseased worms? As a result of his experiments with this aspect of the problem he threw himself down one day in a laboratory chair, utterly discouraged, saying: "Nothing is accomplished; there are two diseases."

Nevertheless he saw the way out, and found ultimately that this second disease, known as flacherie, is entirely intestinal like human typhoid or cholera, and is due to a widely distributed bacillus. Worms with reduced vitality; worms in unhealthful surroundings succumb to it, while healthy and well cultured worms, although they may harbor the bacillus, do not become diseased. To prevent it he proved that it is only necessary to rear the larvae in clean, well ventilated hatcheries. From these six years of study Pasteur got

a deep and lasting impression first, of the idea of receptivity or susceptibility of individuals to germs; second, of the effect of unsanitary conditions in enhancing this susceptibility; third, of the idea of pre-disposing hereditary conditions and defects; and fourth, of the idea of differences in virulence of different strains of the same organism of disease This last idea he developed later in studies on attenuation and vaccines

Some further groundwork was necessary, however, before he was to throw the light of his imagination over the dark field of human disease The occasion for this was furnished by the Franco-Prussian war when, in 1871, without opportunity or finances to carry out his dreams of research, he was persuaded to study the manufacture of beer in order to save France the expense of importing it from across the Rhine The result of the experiments which followed, and of the book he wrote on the subject, enabled the French brewers to compete successfully with the best products from Germany and Austria. He proved that the diseases of beer are always due to the development of microorganisms which are foreign to good fermentation. One, and a most important discovery, was that yeast and certain molds like Mucor will thrive under proper conditions with oxygen of the air, that is, under aerobic conditions If air is withheld, however, they have the ability to thrive under anaerobic conditions, when, as reducing agents, they get the needed oxygen from the most favorable source, which in fermentation is sugar.

Through other experiments on the diseases of wines he proved that natural fermentation is due to wild yeasts on the surface of the grape, and that such fermentations can be prevented by growing grapes in a properly protected yeast-free soil.

This latter fact led to his first clear statement of possible public prophylaxis against human disease germs: "Must we not believe by analogy," he wrote in 1879, "that a day will come when preventive measures of easy application will arrest human plagues which at one blow desolate and terrify whole populations, as did yellow fever in its recent invasion of the Senegal and the valley of the Mississippi, or the bubonic plague which has raged on the Volga."

Here, finally, the stage was fully set for his last great scene in the drama of microscopic life. Demonstration of the rôle of germs and of their control in the economic life of France, whereby millions of francs were saved annually in the silk, wine and beer industries alone, was introductory to the demonstration and control of their multiple activities in human disease.

Pasteur never qualified as a taxonomist. He apparently never experienced the pleasure of a naturalist in finding and describing

new species. He knew very little about the zoology of the silkworm organism; he cared nothing about morphology as such. It is related that a zealous microscopist once brought to his notice in carefully guarded words the fact that what he had called a coccus was in reality a very small bacillus. "Ah," said he, "if you only knew what little difference that makes to me." His great interest lay in the relations of the microorganism to its host; the relation between the physiological activity of the germ and the physiological activities of the invaded organism. He was not the kind to wade in the shallow waters of classification; if a deep subject appealed to him he dove to the bottom of it.

We have seen that, with fermentation, spontaneous generation and the silkworm diseases, he was not the first to enter the field. So it was with human disease When he began his experimental studies on splenic fever, several pathogenic microbes had already been discovered, and Koch had just published his famous work on the spore of anthrax. He was, however, without precursor in the field which he made his own. No one before him had found out that the vitality of a germ determines the severity of the disease; no one before him was familiar with the conflict which occurs between the human organism on the one hand and the disease-causing organism on the other, he was the first to know of the products of bacterial action which we now call toxines; and no one before had recognized the importance of building up the resistance of the host by use of attenuated germs of the disease. He had to oppose almost single-handed the traditional and accepted view of the medical profession that viruses and living organisms are different things. The old conception of viruses, quite as mystical as Liebig's conception of fermentation, was maintained by many noted pathologists until within a comparatively recent period. The empirical results of vaccination against smallpox were, indeed, known, but the explanation was as remote then as is our knowledge to-day of the life history of the organism which causes it.

When Davaine with Rayer discovered the bacillus of anthrax in 1850 and interpreted it as the cause of the disease, the medical profession scornfully cried: "How can the great strength and vitality of a horse or an ox be threatened and destroyed by this miserable little rod which can be seen only with a microscope?"

The final proof came through application of the method, devised by Pasteur, of growing the organism in pure cultures. The history of splenic fever furnishes an interesting parallel with the silkworm diseases. Leplat and Jaillard had denied the conclusion of Davaine and Rayer that the microscopic rod was the cause of the disease, for, inoculating rabbits with putrid blood from an anthrax victim, the rabbits died and no anthrax bacilli could be found in

them. As the organism of flacherie as well as the organism of pebrine might cause the death of silkworms, so might some other organism kill rabbits as well as the anthrax germ. The proof of this was demonstrated by Pasteur and the group of organisms causing gangrenous septicemia or blood poisoning was discovered. With this proof came also the demonstration of the principle that a common microbe under aerobic conditions may be harmless, while under anaerobic conditions it is pathogenic.

I do not intend to enumerate all of the discoveries made by Pasteur as a consequence of his entry into the field of human diseases. Each successive discovery carried him a little nearer the goal of vaccines and preventive medicine. Working with the vibrio which causes septicemia, he found that cultivation in certain media gave weakened strains, while other media gave fully virulent ones. The significance became apparent in his studies on chicken cholera. Experiments on this latter disease were begun in 1879. The organisms were easily obtained and cultivated on broth; inoculations proved fatal to chickens and rabbits and to guinea pigs if the latter were inoculated in the veins. If guinea pigs were inoculated in the skin only a local abscess was formed and the animal was only slightly affected. It would thus become a carrier or a source of infection for other animals. Some chickens also seemed to recover from the disease, but died after some weeks or months. What was the reason for this relative immunity? The answer came with a clearness which was as startling as it was sudden.

After a vacation of some weeks experiments with the chicken disease germs were renewed. Chickens were inoculated with the old cultures which had been left during the vacation. These chickens did not die nor did they seem to be much affected. After repeated attempts the laboratory staff were about to throw away the old cultures and begin with new ones, when it occurred to Pasteur to inoculate those same chickens with fresh, virulent cultures of the organism. To the surprise of all, including Pasteur himself, these chickens resisted the inoculations and remained normal. Fresh chickens brought from the market and inoculated died of the disease, thus showing the virulent potency of the culture. With these observations and experiments the secret of vaccines was out; attenuation or reduced vitality of the germ so changes it that, upon inoculation, it causes a reaction which enables the victim to successfully resist later inoculations of the same germs in their full virulence.

Studies on vaccines then supplanted all else. It was soon shown that attenuated germs could be maintained permanently in the attenuated condition; that spores from attenuated germs would develop into organisms with the same attenuation, and capsules of

different kinds of vaccines were prepared, ready for shipment to all parts of the world. Every one who has read the life of Pasteur knows about the spectacular demonstration at Melun where out of 50 sheep inoculated with virulent anthrax bacilli, 25 that had been previously vaccinated with attenuated virus, remained alive and normal, while 25 that had not been vaccinated, all died.

The study of animal diseases thus led to principles which, there was every reason to believe, would apply with like results to human diseases. Splenic fever, due to the anthrax germ, indeed sometimes occurs in man, but its occurrence is so rare that it arouses no apprehension.

It was quite otherwise with rabies or hydrophobia. Here was a disease the thought of which brought terror to every living soul, and it was to this disease that Pasteur brought to bear the full weight of his experience with microorganisms. Again using animals, dogs in particular, he was able to study every phase of the disease. The seat of infection was traced back from the saliva to the central nervous system; inoculation by trepanning was found to be the quickest and most effective means, and fragments of infected brain or spinal cord would invariably convey the disease. Repeated experiments proved that attenuation of the germ, which by the way has never been isolated, is brought about by exposure of the infected tissues to the air. Strips of such tissue were thus exposed daily for a period of 15 days and, in treating humans, the victim of a rabid animal was first inoculated with the material from a strip 15 days old; then after 24 hours, with a strip exposed for 14 days and so on until the victim was inoculated without harm with material taken fresh from a rabid animal. Such treatment of rabies was possible, and effective, because of the long incubation period of weeks or months in a human being after infection.

This was the crowning work of Pasteur's life; to us it was the last stride in a long series of logical steps; to the popular mind, especially in France, it was a miracle. Almost every one in France was happy to contribute at least a few sous for the erection in 1888 of a monument to Pasteur. In this monument, the Pasteur Institute, on the rue Dûtot in Paris, Pasteur, weakened by a stroke of paralysis in 1868, spent the last years of his life. In it to-day, characteristic activity in all matters pertaining to disease still keeps alive the traditions of the master.

On the occasion of his reception in the Académie Française, Pasteur was thus addressed by Ernest Renan: "That common basis of all beautiful and true work, that divine fire, that indefinable breath which inspires Science, Literature and Art—we have found it in you. Sir, it is genius."

The debt of biology, the debt of medicine, the debt of all science to Pasteur is a debt to that indefinable breath of which Renan

spoke, and no one branch of science can claim a monopoly of Pasteur's genius

Reviewing from the vantage point of to-day the position which Pasteur occupies in the history of science, free now from the shocks to prejudice and superstition which followed in apparently endless succession from his work, it would seem that the greatest expression of his genius lay in the glorification of scientific method—observation, deduction, experimental proof. Through these things his life-work, in the words of Renan again, "is like unto a luminous track in the great night of the infinitesimally small; in that last abyss where life is found."

Vallery-Radot quotes Pasteur as saying on one occasion: "A man of science should think of what will be said of him in the following century, not of the insults or the praise of one day."

In commemorating Pasteur's birth, audiences throughout the civilized world have heard little or nothing of the insults, but in this "following century" have united in one great wave of praise. He did become a teacher as his father so ardently wished, not indeed in the humble college at Arbois, not only at the great universities of Strasbourg, Lille and the École Normale, but a teacher at whose feet the entire world still sits in grateful appreciation.

How can we compare the life of Pasteur and of that other great scientist the centenary of whose birth was also commemorated last year—Gregor Mendel? Mendel was born in July, 1822; Pasteur on December 27 of the same year. I know of no other two scientific men whose lives present so striking a contrast. The one, working for fifty years in the spotlight of public approval, planned and developed every stage in the construction of a marvelous scientific edifice on foundations which he himself had laid The other, working for seven years in the cloistered seclusion of a monastery at Brünn, alone knew that his work was good. Its full value he never knew. The one, full of honors, received from all lands, ending his career peacefully amid the scenes of his triumphs; the other, spending the later years of his life in fruitless wrangling, died comparatively unknown. The one saw as a result of his work the foundations of stereo-chemistry, of the germ theory of disease, of bacteriology, of serology and of preventive medicine; the other had been gone many years before his great service to the science of genetics was known and recognized.

Both were alike in devotion to truth; both were alike in respect to patience and perseverance in experimentation, and in attention to detail. Both had imagination.

The recognition of Mendel's genius, though tardy, has been generous, sincere and universal. This following century has now crowned him, as the last century did Pasteur, with the wreath of immortality.

THE CENTENARY OF LOUIS PASTEUR[1]

Pasteur and the Science of Chemistry

By Professor JOEL H. HILDEBRAND
UNIVERSITY OF CALIFORNIA

You who have come this evening to honor the memory of Louis Pasteur have been familiar, even from childhood, with some of his contributions to science other than chemistry. You drink pasteurized milk. You have learned that certain diseases are caused by germs and that it is possible to prepare anti-toxins which will come to our rescue when our bodies are invaded by alien hosts of bacteria. On the other hand, the nature of his contributions to chemistry is not easily understood and their significance is not generally appreciated by the laity, so that it would be quite excusable for you to wonder what justification there may be for my presence upon this platform You may not have known before this evening that Pasteur was educated as a chemist and devoted himself chiefly to research in pure chemistry during the first years of his research career, and further, that during this time he made discoveries of fundamental importance, probably not inferior in value to those later discoveries in other fields which are the objects of more popular appreciation.

Since this is the case, and since his own work can speak louder in his praise than anything else, it is my purpose to endeavor to explain something of the nature and significance of his chemical contributions during this period. As a chemist I hasten to add that I do not abandon all claim in behalf of chemistry for a share in the glory of his later work. Much of it is still chemistry though shared with what we are pleased to call other branches of science, and I may even venture to suggest that he was helped to some of his later discoveries by his unusually good training in the more fundamental science, and through his fortunate escape from the large measure of traditional dogma which he would have been taught, at least at that time, had he been trained chiefly in medi-

[1] Delivered at the Pasteur Centennial celebration at the University of California, February 1, 1923. The address on "Pasteur and the Science of Biology" by Professor Charles Atwood Kofoid was printed in THE SCIENTIFIC MONTHLY for June.

cine or surgery. A fresh point of view is of great value in scientific discovery.

But I will not risk retort from my colleagues to follow by further disputing the field with them, and I therefore return to my main purpose.

In 1808, 14 years before the birth of Pasteur, Malus had discovered that light can be polarized. A beam of light transversing a crystal of iceland spar is broken up into two beams in which the vibrations are at right angles to each other, instead of occurring in all directions as in the ordinary beam. By a suitable cutting of the crystal, making what is known as a nicol prism, one of these beams can be disposed of, leaving a single beam of polarized light. If a second nicol prism is placed behind the first, and in the same position, the light polarized by the first passes through the second unchanged; but if the second prism is rotated 90 degrees, so that the two prisms are "crossed," the light polarized by the first can not pass through the second.

In 1815, Biot, who later became a staunch friend and patron of Pasteur, discovered that, if between the crossed nicol prisms there is placed a plate of quartz, or any one of several liquids, including turpentine and solutions of sugar, camphor and tartaric acid, one of the prisms must be rotated in order again to extinguish the light, showing that these substances rotate the plane of polarization.

The mineralogist Haüy had discovered the existence of two kinds of quartz crystals, exactly alike except that one corresponds to the mirror image of the other, as do the right and the left hands, and which can not be made to coincide any more than a right hand can wear the left-handed glove. In these crystals the possible faces are not all present, some being present on the right-hand corners of certain other faces, while in other crystals they are present on the left-hand corners. Such crystalline forms are known as hemihedral or asymmetric.

In 1820, Sir John Herschel connected this hemihedrism with the rotation of the plane of polarized light, pointing out that one kind of quartz crystal rotates the plane of light to the right, while the other rotates it to the left.

The next step was a presentation to the Académie des Sciences by Biot of a remarkable note by Mitscherlich concerning certain salts of tartaric acid, the acid of grapes. It was as follows: "The double paratartrate and the double tartrate of soda and ammonia have the same chemical composition, the same crystalline form with the same angles, the same specific weight, the same double refraction, and consequently the same inclination in their optical axes. When dissolved in water their refraction is the same. But the dis-

solved *tartrate* deviates the plane of polarization, while the *para*-tartrate is indifferent, as has been found by M. Biot for the whole series of those two kinds of salts. Yet," adds Mitscherlich, "here the nature and number of the atoms, their arrangement and distances are the same in the two substances compared."

Pasteur in his own later account of his discovery says:

This note of Mitscherlich attracted my attention forcibly at the time of its publication. I was then a pupil in the École Normale, reflecting, in my leisure moments, on this elegant investigation of the molecular constitution of substances [would that there were more students who would use their leisure moments for such reflections and for reading such as Pasteur did! But to continue the quotation] and having reached, as I thought, at least a thorough comprehension of the principles generally accepted by the physicists and chemists. The above note disturbed all my ideas. What precision in every detail! Did two substances exist which had been more fully studied and more carefully compared as regards their properties? But how, in the existing condition of the science, could one conceive of two substances so closely alike without being identical? Mitscherlich himself tells us what was, to his mind, the consequence of this similarity: "*The nature, the number, the arrangement and the distance of the atoms are the same.*" If this is the case, what becomes of the definition of chemical species, so rigorous, so remarkable for the time at which it appeared, given by Chevreul in 1823—"in compound bodies a species is a collection of individuals identical in the nature, the proportion and the arrangement of their elements."

In short, Mitscherlich's note remained in my mind as a difficulty of the first order in our mode of regarding material substances.

You will now understand why, being preoccupied, for the reasons already given, with a possible relation between the hemihedry of the tartrates and their rotative property, Mitscherlich's note of 1844 should recur to my memory. I thought at once that Mitscherlich was mistaken on one point. He had not observed that his double tartrate was hemihedral while his paratartrate was not. If this is so, the results in his note are no longer extraordinary, and further, I should have, in this, the best test of my preconceived idea as to the interrelation of hemihedry and the rotatory phenomenon.

I hastened, therefore, to reinvestigate the crystalline form of Mitscherlich's two salts. I found, as a matter of fact, that the tartrate was hemihedral, like all the other tartrates which I had previously studied, but, strange to say, the paratartrate was hemihedral also. Only, the hemihedral faces which in the tartrate were all turned in the same way, were, in the paratartrate, inclined sometimes to the right and sometimes to the left. In spite of the unexpected character of this result, I continued to follow up my idea. I carefully separated the crystals which were hemihedral to the right from those hemihedral to the left, and examined their solutions separately in the polarizing apparatus. I then saw with no less surprise than pleasure that the crystals hemihedral to the right deviated the plane of polarization to the right, and that those hemihedral to the left deviated to the left; and when I took an equal weight of each of the two kinds of crystals, the mixed solution was indifferent toward the light in consequence of the neutralization of the two equal and opposite individual deviations.

Pasteur gives us evidence at this point of that intense curiosity concerning nature's secrets without which no one becomes a scien-

list. He rushed out of the room and, finding a curator, embraced him and cried, "I have just made a great discovery; I am so happy I am trembling so I can hardly put my eye to the polariscope again." Some years after he said, "The study of these acids is of immense interest. I do not know any that is more interesting." A very different object of interest, you will admit, from those which arouse the ordinary mind.

The first to appreciate the significance of Pasteur's discovery was naturally Biot, who with his own hands tested crystals which Pasteur obtained in his presence. When the result was achieved the old man in his enthusiasm took Pasteur by the arm and said, "My boy, I have loved science so much throughout my life that this makes my heart throb."

Pasteur was but 26 when he made this discovery. It at once brought him into prominence in the scientific world. His further studies included two further methods for separating such asymmetric substances from each other. One consisted in the combination of the acid with a naturally occurring optically active base, giving rise to two salts which now no longer rotated in opposite directions to an equal extent, and which therefore were no longer identical in other respects, so that they can be separated by fractional crystallization. The other method resulted from the discovery that a certain ferment would destroy one of these acids in the racemic mixture, paratartaric acid, leaving the other unchanged. This work with ferments was the opening door to most of his later work in the field of biology. These methods for separating optically substances are to-day the only ones which we possess.

Pasteur further called attention to a problem which still remains one of absorbing scientific interest. Whenever asymmetric substances are prepared in the laboratory from inactive substances, the chance rearrangement of atoms favors neither the right nor the left-hand form, so that the result is always a racemic mixture, composed of right and left-handed forms in equal amount. Nature, however, for some reason still unknown to us, is able to produce a single form, such as dextro-rotatory cane sugar and spiral bacteria all twisted in the same direction. The explanation of this extraordinary fact has yet to be furnished.

Pasteur discovered still another form of tartaric acid, inactive, like the racemic mixture of dextro and laevo forms, but this time because the molecule is *internally* compensated, one end being right-handed, the other left-handed. He also indicated the probable arrangement of the atoms in the molecules to account for the various forms discovered. These ideas were further developed independently by Le Bel, in France, and by van 't Hoff in Holland, and

have finally given us very definite evidence concerning the spatial arrangement of atoms in molecules.

I shall endeavor to explain this arrangement for the tartaric acids by the aid of models.

You are doubtless inclined to consider a discovery of this sort as of academic interest only, and of far less importance to mankind than the later work of Pasteur. May I, therefore, point out the fundamental importance to human welfare of the knowledge of the constitution of chemical molecules; a knowledge which has enabled us, like architects, to draw plans of molecules and to lop off or add or substitute parts of these molecules in order to attain a desired result. The artificial synthesis of a host of natural products and of products which in many cases are improvements upon those of nature rests upon knowledge gained in part through this important work of Pasteur.

May I call your attention in this connection to the words of Pasteur himself, who, with his customary deep insight, said:

> Without theory practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention. It is to you specially that it will belong not to share the opinion of those narrow minds who disdain everything in science which has not an immediate application. You know Franklin's charming saying? He was witnessing the first demonstration of a purely scientific discovery, and people around him said. "But what is the use of it?" Franklin answered them: "What is the use of a new-born child?" Yes, gentlemen, what is the use of a new-born child? And yet, perhaps, at that tender age, germs already existed in you of the talents which distinguish you! In your baby boys, fragile beings as they are, there are incipient magistrates, scientists, heroes as valiant as those who are now covering themselves with glory under the walls of Sebastopol. And thus, gentlemen, a theoretical discovery has but the merit of its existence; it awakens hope, and that is all. But let it be cultivated, let it grow, and you will see what it will become.
>
> Do you know when it first saw the light, this electric telegraph, one of the most marvelous applications of modern science? It was in that memorable year, 1822: Oersted, a Danish physicist, held in his hands a piece of copper wire, joined by its extremities to the two poles of a Volta pile. On his table was a magnetized needle on its pivot, and he suddenly saw *(by chance, you will say, but chance only favors the mind which is prepared)* the needle move and take up a position quite different from the one assigned to it by terrestrial magnetism. A wire carrying an electric current deviates a magnetized needle from its position. That, gentlemen, was the birth of the modern telegraph. Franklin's interlocutor might well have said when the needle moved: "But what is the use of that?" And yet that discovery was barely twenty years old when it produced by its application the almost supernatural effects of the electric telegraph!

How much more we can add to-day to the list of fruits of this discovery: the dynamo, the electric motor, the electric light, the trolley car, the telephone, vanadium steel, carborundum, artificial graphite and a host of others, all made possible by this one discov-

ery! And such for chemistry was the discovery I have just outlined. Of what use was it? Of more use than all of the work of European politicians together in the year 1848!

I may be permitted, in closing, to refer briefly to another fruit of the life of Pasteur. Science is sometimes reproached as contributing only to the material well-being of mankind. I would assert on the contrary and with all boldness that nothing could be farther from the truth. Science has made a spiritual contribution of the utmost value, and in many respects unique. This contribution has been superlatively illustrated in the life and character of Pasteur. No one, I imagine, can read his life without being impressed by his constant, conscientious, unselfish devotion to the pursuit of truth; not the conception of truth which for ages has cursed mankind, which is represented by tradition and dogma, whose extension is sought by the method of the Inquisition, by stifling freedom of thought and inquiry; but rather the truth as determined by the scientific method of carefully questioning Nature, and honestly, eagerly and intelligently interpreting her responses. This is the only method for the discovery of truth which has shown itself abundantly able to yield the truth.

We see Pasteur pursuing this quest now in one realm, now in another, but always with a pressing sense of duty which allows him no respite even upon the sickbed; which prevents him from pausing to gather wealth from the consequences of his labors, although, as Huxley said, he created wealth for France which more than sufficed to pay the German indemnity. Here was a man who will long serve as an inspiration to those who try to follow the same quest. The world is far richer spiritually, as well as materially, from his presence.

His own words in closing a lecture upon molecular asymmetry serve as a fitting close to these words of mine:

> Such, gentlemen, are in coordinated form the investigations which I have been asked to present to you.
>
> You have understood, as we proceeded, why I entitled my exposition, "On the Molecular Asymmetry of Natural Organic Products." It is, in fact, the theory of molecular asymmetry that we have just established, one of the most exalted chapters of the science. It was completely unforeseen, and opens to physiology new horizons, distant, but sure.
>
> I hold this opinion of the results of my own work without allowing any of the vanity of the discoverer to mingle in the expression of my thought. May it please God that personal matters may never be possible at this desk. These are like pages in the history of chemistry which we write successively with that feeling of dignity which the true love of science always inspires.

Pasteur and the Science of Bacteriology

By Professor J. G. FITZGERALD, M.D., F.R.S.C.
UNIVERSITY OF TORONTO

AN account of the work of Pasteur in the field of bacteriology requires to be prefaced by the observation that prior to his time the foundations of this science had not been laid. To very few men is given the opportunity of charting the course, however roughly, of a new branch of science in the immense ocean of the unknown. Still fewer possess the unconquerable spirit and the genius to strike out boldly and surely, and to reach the haven of immense achievement and solid and enduring contribution to science and human welfare. This, however, was the destiny of Pasteur, and to-day, one hundred years after his birth, and nearly twenty-eight years after his death, he is in even the most remote corners of the world being acclaimed as one of the greatest benefactors of humanity who has ever lived.

Pasteur's preliminary scientific training was very broad and thorough. He took immense pains to acquire a substantial background of mathematics and the natural sciences, physics, chemistry and biology. There was, of course, very much less differentiation of and distinction between these three branches of natural science seventy-five years ago. It was quite possible for a scholar of that time to become an authority in all three fields. to keep abreast of new developments and at the same time to make substantial contributions to all of them.

Pasteur's earliest work was in the field of chemistry. Between 1845 and 1855 his attention was directed almost entirely to the solution of problems which were only indirectly related to biology and to bacteriology. His studies in stereochemistry and subsequently in fermentation proved to be the bridge over which he crossed to enter the realm of bacteriology. The authority of the great chemists Berzelius and Liebig was such at this time that their theories of the nature of fermentation were everywhere accepted. Liebig's explanation of chemical decomposition or fermentation was that a ferment or influence (this being an unstable organic substance) in decomposing set in motion, as a result of the rupture of its own elements, the loosely bound molecules of the fermentable matter. In other words, the part of the yeast which produced fermentation was an altered, dead portion, acting upon sugar. According to this it was not the result of vital activity; in other

words, it was not a physiological process. Pasteur, as was his invariable custom, submitted the question to experimentation. Through scientific investigation he felt convinced this problem could be solved and in no other way. Fruitless speculation had too long delayed the elucidation of the question. Pasteur was at this time, 1856, professor and dean of the Faculté des Sciences at Lille. Here many opportunities for the study and investigation of the processes of fermentation presented themselves.

He examined with his microscope the fluids in which fermentation was proceeding He observed the shape of the living micro-organisms in these fluids. He correlated his microscopic findings with the results obtained on many occasions in the process of fermentation with different fluids containing a variety of micro-organisms Pasteur established the fact that when certain micro-organisms were present the fermentative changes resulted in the recovery of satisfactory products; when other forms were present, the contrary was the case. Schwann and Cagniard-Latour, the latter a French physicist of distinction, had prior to this time observed that the ferment was composed of yeast cells and that they reproduced by budding. They also speculated that these yeast cells probably acted upon sugar through some effect of their vegetation. Pasteur continued his experiments on both lactic acid and alcoholic fermentation and soon he had convinced himself that fermentation of any sort was due to the activities of a living micro-organism. He found that different types of fermentation were due to different varieties of these micro-organisms. In this, as in other investigations, Pasteur presented the results of adequate and carefully controlled experiments, where others had been satisfied with a few observations and much speculation. The paper on lactic acid fermentation was presented before the Lille Scientific Society in August, 1857. Later during the same year a paper on alcoholic fermentation was read before the Académie des Sciences in which he declared that his experiments showed that the splitting of sugar into alcohol and carbonic acid was due to the activities of organized living agents, "microscopic globules." It was a physiological process.

These were the first correlated studies of morphology and biochemical activities of bacteria ever made and were completed at a time when there was no technique for the isolation of bacteria in pure culture, no methods of sterilization and no definite criteria for the differentiation of bacterial species. Parenthetically, it may be added, it was also prior to the time when any bacterial species had indubitably been shown to be the etiological agent of a disease process in man or lower animals.

At this time a firm belief in spontaneous generation (generatio aequivoca) was not the exclusive possession of children, pseudo-philosophers or the illiterate. On the contrary it was very widely held The doctrine, "omne vivum e vivo" or "omne vivum ex ovo," while strongly supported by the earlier work of Spallanzani had many more enemies than friends. For the next five years (1765) Pasteur devoted himself assiduously to scientific experimentation aimed at the elucidation of this problem as well as continuing his studies of fermentation and putrefaction. In 1861 in conducting experiments on butyric acid fermentation Pasteur made the very fundamental observation that certain micro-organisms developed only in the absence of free oxygen Thus the first discovery relating to anaerobiosis as well as the varying oxygen requirements of different bacteria was made.

In the meantime a very bitter scientific controversy was being waged about the question of spontaneous generation—several scientific workers in France as well as others elsewhere were not disposed to admit that Pasteur was right when he concluded as a result of a long series of experiments that the appearance of living micro-organisms in fluid contained in flasks, etc , was due to the contamination of the fluid by air containing organized bodies.

Infusions of organic matter were made. They were clear when first prepared. They were then exposed to heat, even to boiling. Unless carefully protected from dust particles they soon became cloudy and if examined were found to contain innumerable micro-organisms Pasteur's own words quite explicitly and concisely indicate how he once and for all disposed of the question of spontaneous generation. He wrote:

> I place a portion of that infusion into a flask with a long neck, like this one. Suppose I boil the liquid and leave it to cool. After a few days, mouldiness or animalculae will develop in the liquid. By boiling, I destroy any germs contained in the liquid or against the glass; but that infusion being again in contact with air, it becomes altered, as all infusions do. Now suppose I repeat this experiment, but, before boiling the liquid, I draw (by means of an enameler's lamp) the neck of the flask into a point, leaving, however, its extremity open. This being done, I boil the liquid in the flask and leave it to cool. Now the liquid of this second flask will remain pure not only for two days, a month, a year, but three or four years—for the experiment I am telling you about is already four years old, and the liquid remains as limpid as distilled water. What difference is there, then, between those two flasks? They contain the same liquid, they both contain air, both are open! Why does one decay and the other remain pure? The only difference between them is this: in the first case, the dusts suspended in air and their germs can fall into the neck of the flask and arrive into contact with the liquid, where they find appropriate food and develop; thence microscopic beings. In the second flask, on the contrary, it is impossible, or at least extremely difficult, unless the air is violently shaken, that dusts suspended in air should enter the flask; they fall on its curved neck.

When air goes in and out of the flask through diffusions or variations of temperature, the latter never being sudden, the air comes in slowly enough to drop the dusts and germs that it carries at the opening of the neck or in the first curves.

This experiment is full of instruction; for this must be noted, that everything in air, save its dust, can easily enter the flask and come into contact with the liquid. Imagine what you choose in the air—electricity, magnetism, ozone, unknown forces even, all can reach the infusion. Only one thing cannot enter easily, and that is dust, suspended in air. And the proof of this is, that if I shake the flask violently two or three times in a few days it contains animalculae or mouldiness. Why? Because air has come in violently enough to carry dust with it.

And, therefore, gentlemen, I could point to that liquid and say to you, I have taken my drop of water from the immensity of creation, and I have taken it full of the elements appropriated to the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb, dumb since these experiments were begun several years ago; it is dumb because I have kept it from the only thing man can not produce, from the germs which float in the air, from Life, for Life is a germ and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment.

Pasteur's work on fermentation was a logical preliminary to his attempt in 1864 to determine the cause of the disease of wines which entailed very considerable economic losses in certain districts in France. He concluded after careful morphological studies of the micro-organisms found in the wines that "the alterations of wines are co-existent with the presence and multiplication of microscopic vegetations." Certain concrete proposals were made by Pasteur at this time, which, had they been adopted, would have controlled the undesirable fermentative activities in wines. The thermal death point of these micro-organisms was ascertained very definitely. These were the first accurate experimental studies of thermal death points of bacteria. . Between the years 1865 and 1870 Pasteur was engaged in a series of investigations in an effort to discover the cause of an epidemic which was ravaging the silkworms and threatening the very life of sericulture in France. This fascinating chapter of achievement properly belongs in the category of work in protozoology and so will not be dealt with here.

We have now reached the place in Pasteur's scientific life where he was about to scale the heights and to achieve enduring fame. The philosophic conception that certain human and animal diseases which manifested pronounced communicability and appeared in pandemic or epidemic outbursts were really due to living agents or "contagium vivum" was expounded at regular intervals. About 1666 Robert Boyle, an English physicist at Oxford, had expressed the conviction that the solution of the problem of the nature of ferments would do much to explain certain phenomena of disease.

Pasteur was very greatly impressed by this and in his mind's eye saw clearly the possible relationship of minute living agents to communicable diseases. But vague speculation was to have no place in the program which Pasteur marked out to test the validity of this conception. Accurate and careful observation, correlated with splendidly conceived and wisely controlled experiment, was alone depended upon to reveal the truth.

The work in 1871 on cultures of yeasts of value in brewing led to the development of an exact technique for sterilization, the so-called method of pasteurization or fractional sterilization. This added much to the methodology of the embryonic science of bacteriology. In 1874, before the etiological relationship of any bacterial species to a disease process had been conclusively established, Joseph Lister, later Lord Lister, a Scottish surgeon, who had read and profited by Pasteur's work on lactic acid fermentation, wrote to Pasteur as follows:

My dear Sir—Allow me to beg your acceptance of the pamphlet, which I send by the same post, containing an account of some investigations into the subject which you have done so much to elucidate, the germ theory of fermentative changes. I flatter myself that you may read with some interest what I have written on the organism which you were the first to describe in your "Memoire sur la fermentation appelée lactique."

I do not know whether the "Records of British Surgery" ever meet your eye. If so, you will have seen from time to time notices of the antiseptic system of treatment, which I have been laboring for the last nine years to bring to perfection.

Allow me to take this opportunity to tender you my most cordial thanks for having, by your brilliant researches, demonstrated to me the truth of the germ theory of putrefaction, and thus furnished me with the principle upon which alone the antiseptic system can be carried out. Should you at any time visit Edinburgh, it would, I believe, give you sincere gratification to see at our hospital how largely mankind is being benefited by your labors.

I need hardly add that it would afford me the highest gratification to show you how greatly surgery is indebted to you.

Forgive the freedom with which a common love of science inspires me, and

Believe me, with profound respect,

Yours very sincerely,

JOSEPH LISTER

The foundations, first, of antiseptic and later of aseptic surgery were thus laid by Pasteur. He at this time very definitely advised the sterilization of all surgical instruments before use by passing them through a living flame and he also recommended the sterilization of all surgical dressings by heating to a temperature of 150° C. before being used. He also proposed that plugs of cotton wool should be used to stopper glass vessels containing sterile fluids to prevent the entrance of organic matter containing living micro-organisms.

In 1838 Delafond, of the Alfort Veterinary College, saw in the blood of cattle that had died of anthrax "little rods" to which he attached no significance. In 1850 Davaine and Royer repeated the work of Delafond but without appreciating its significance. Davaine in 1863 read Pasteur's paper on (the cause of) butyric acid fermentation and was greatly impressed by it, and in 1863 he again examined the blood from sheep that had died of anthrax and found in it tiny bodies which he called "bacteridia." He announced that he believed these were the cause of anthrax. Various workers now took up the question and very soon the whole subject was completely obscured by contradictory and conflicting results.

Pasteur undertook to investigate the question. He took a small amount of blood from an animal that had died of anthrax, and with all aseptic precautions planted it in a sterile flask containing a slightly alkaline, sterile culture medium. In this medium he grew pure (single) cultures of anthrax bacilli. He noted the characteristic growth of these micro organisms. He subcultured his growths by carrying over from flasks in which the bacilli were growing a few drops to other flasks of sterile culture medium, thus seeding them and permitting new generations of these microbes to appear.

The next step consisted in establishing that the germs which were thus grown in an artificial culture medium were really the causative agents of the disease anthrax. This was done by the injection into susceptible animals of a drop of culture material from the flasks The animals so injected developed anthrax and from their blood anthrax bacilli were recovered. Thus the etiological relationship of a species of micro-organism to the disease anthrax was conclusively established. The way was now prepared for the complete investigation, through the application of similar methods, of all the communicable diseases. Pasteur announced it as his belief that "each infectious disease is produced by the development within the organism of a special microbe." Between 1877, when Pasteur completed his work on anthrax, and 1895, the year of his death, the causative agents of nearly all the important communicable diseases were discovered.

To this very remarkable accomplishment Pasteur contributed the lion's share in elaborating technical procedures, formulating criteria by which results could be appraised and by a rigid insistence on the necessity for most exact experimental verification of all opinions expressed or views advanced. Such remarkable achievements would in the vast majority of cases have marked the climax of scientific contribution. Such, however, was not the case with Pasteur. His great vision led him to develop specific methods of inestimable benefit to the human race for the prevention of many communicable diseases.

In all of this he was guided by ideals which were embodied in the declaration, "Blessed is he who carries within himself a God, an ideal, and who obeys it; ideal of art, ideal of science, ideal of the gospel virtues, therein lie the springs of great thoughts and great actions; they all reflect light from the Infinite." In no small measure the improvements noted in the state of the public health in the last two decades in the United States as elsewhere are the fruits of Pasteur's labors. Thus through the application of the methods of preventive medicine in the past fifty years in this country the span of life on the average has increased 15 years, forty-one years being the average length of life in 1870, whereas it was 56 in 1920. In the past twenty years also the infant mortality rate has been reduced one third, the tuberculosis death-rate cut in half and the deaths from typhoid fever reduced to one fifth of their former number These are some of the reasons why a grateful posterity should pause to pay homage to the memory of Louis Pasteur.

Pasteur and the Science of Medicine

By Professor W. P. LUCAS, M.D.
UNIVERSITY OF CALIFORNIA MEDICAL SCHOOL

SOME one has said of Pasteur "that he did more than make discoveries; he discovered how to make them." In his long fight to convince the medical profession of the value that lay in the discoveries he had made as a chemist in the laboratory, he constantly stressed the point that such discoveries as had come from his studies of fermentations, of so-called spontaneous generation, of silkworm diseases, splenic fever, chicken cholera and the rest were but the establishment of methods which would lead to a new world of medicine. Bitter hostility came to him—how dared this chemist, successful as he might be in the protection from disease of silkworms and sheep, suppose that the field of medicine, about which he knew nothing, could accept his conclusions that struck at the very roots of the traditional dogmas of their profession? But hostility never made Pasteur hostile. He invited his enemies into his laboratory and with a divine patience demonstrated the methods by which his conclusions were reached.

In speaking one day to a group of students in the Medical Academy, who sat before him in varying moods of hostility, indifference and scepticism, his deep voice rang out a challenge, "Young men, you who sit on these benches, and who are perhaps the hope of the

medical future of the country, do not come here to seek the excitement of polemics, but come and learn method."

In all the struggle, he never asked medical men to believe in him but to believe in the methods which were being established by actual proofs which could be demonstrated to the open mind. The stories of the conflicts which he had all reveal the openness of his own mind, his desire for criticism, his honest search for truth in the field of science Hurrying into a lecture one day on a subject new and full of infinite possibilities, he said to one of his men: "Do repeat to me every criticism you hear. I much prefer them to praise, barren unless encouragement is wanted, which is certainly not my case. I have a lasting provision of faith and fire." As he said another time, full of that faith and fire, "The breath of Truth is carrying medicine toward the fruitful fields of the future."

As Vallery-Radot says of him, "He had that intuition which makes a great poet out of a great scientist." In the story of his life from beginning to end these two souls, the poet and the scientist, walked side by side. Every discovery made in the laboratory was always accompanied by a flash of light, as it were, which would reveal to him for a moment the next field far ahead. But he never credited himself with anything but the capacity for hard work. In speaking to some students, he said "that it was through assiduous work, with no special gift but that of perseverance joined to an attraction towards all that is great and good, that he had met with success in his researches." The scientist, Pasteur, kept the poet, Pasteur, well in hand. He insisted always upon experimental proofs—whatever that flash of light had revealed to him, he knew there was but one way to convince others and that way was the way of experimental method. Nothing irritated him more than the slightest error in reporting results, or fulsome praise of him that claimed more than had been proved.

In the attempt in a few moments to pay a tribute to Louis Pasteur's contribution to medicine, I am glad that the bacteriologist, the chemist, the protozoologists have spoken and have given you the picture of that chemist whom the medical profession of the day were sometimes bitterly reluctant to accept as a co-worker in the field devoted to the preservation of human life. As Duclaux, the director of the Pasteur Institute, upon Pasteur's death said: "We see also that the physicians were right in treating him as a chemist. They were wrong only in pronouncing this name with a disdainful air. With Pasteur, chemistry took possession of medicine and we can foresee that it will not relinquish its hold."

Surgery extended the first warm welcome to Pasteur and his revelation of "The kingdom of infinitely small things" brought to

that great surgeon Lister the weapon he needed in his fight for antisepsis and asepsis. Lister had been following closely Pasteur's studies in fermentation and when Pasteur proved in 1865 that putrefaction was a fermentation caused by the growth of microbes and these could not arise de novo in the decomposable substance, Lister had, at last, firm ground under his feet, in fighting the scourge of surgery, putrefaction in open wounds. Surgery up to this time had been a ghastly arena of suppurating wounds. Now germs must be killed and no more must be allowed to get into the wound. What Pasteur demonstrated in filtered air in flasks, Lister worked out for the man with a dirty lacerated wound. The truth of the germ theory of putrefaction led to the final success of the antiseptic system Lister had worked over for years. It must have been a great moment to have shared in when years later, on Pasteur's seventieth birthday, the great English surgeon stood in the crowded amphitheater of the Sorbonne and, representing the Royal Academy of London and the Royal Society of Edinburgh, brought to Pasteur the homage of medicine and surgery.

"Truly," said Lister, "there does not exist in the whole world an individual to whom medical science owes more than to you. Your researches on fermentations threw a powerful light which has illuminated the dark places in surgery and has changed the treatment of wounds from an uncertain, emperic and too often disastrous business into a scientific and certainly beneficial art. Thanks to you, surgery has undergone a complete revolution which has deprived it of all its terrors and which has increased its efficacy to an almost unlimited extent."

In October 19, 1868, Pasteur at the age of 46, in the final work on the diseases of the silkworm, suffered a stroke of paralysis. His life was despaired of—at least all idea of active, productive life was over, many thought. Work was stopped upon his precious chemical laboratory to be built by the state because the general feeling was that without Pasteur such a laboratory was an unnecessary investment of money. He had made as yet no direct contribution to medicine. English surgery was profiting, but French surgery still scoffed at the germ theory. Pasteur at first thought he was doomed to die, but slowly that indomitable spirit and clear mind fought its way back to productivity and from 1868 to 1880 he laid the foundation stones of modern medicine. To be sure, it was anthrax, chicken cholera, swine fever, the working out of the protective treatment on animals to which he gave his strength, but by 1880 he had discovered how to attenuate the virus of chicken cholera—in another year he knew how to intensify the virus of anthrax by inoculating with an attenuated virus a series of newly born guinea pigs.

To be able to bring down a virus step by step from full virulence to non-virulence—to be able also to exalt a virus step by step from non-virulence to full virulence, he was able to obtain his standard virus—to measure the exact strength of a virus and to calculate the exact effect upon an animal. So with graduated series of attenuations of the virus, he was able to confer immunity against the disease itself. But it was five years before he took the final step from animal to man, and the terrible scourge of hydrophobia or rabies common to Europe at that time determined him to make his first effort there. Rabies was always fatal, and to the mind and heart of Pasteur, whose kindness was a living flame, it made his final step easier to attack a disease from which there were no known recoveries.

The experiments with the saliva of mad dogs were thrilling and dangerous—but Pasteur knew no fear of that kind. Perhaps his first real fear was in the presence of Joseph Meister, the little boy of nine terribly bitten by a mad dog, who was brought to him July 6, 1885, by a poor frightened mother from Alsace. The story of that first trial to save a human life should be read by all. The tender anxiety of Pasteur, the sleepless nights, the anguish of fear that the child would die, the gradual realization that the truth of his laboratory experiments had been convincingly proved brought a joy to Pasteur no words can describe. The future would see, as Lister said, the veil raised which for years had covered infectious diseases. The question of the return of virulence is, Pasteur declared, of the greatest interest for the etiology of contagious diseases The attenuation and reinforcement of virus have been the guiding stars of modern medicine. Three years after little Joseph Meister recovered, in 1888 the great Pasteur Institute at Paris was opened and Pasteur entered, "a man vanquished by time" as he said, because of increasing age from heavy work, but the light had constantly flashed from his tireless brain and spirit. He was convinced that diphtheria, typhoid, cholera, yellow fever could all be conquered. He would not live to see it, but upon his work it has all been accomplished. It had taken him thirty years to establish just three scientific conceptions of undreamed of service to medicine: *First,* each fermentation is produced by the development within the organism of a special microbe; *second,* each infectious disease is produced by development within the organism of a special microbe; *third,* the microbe of an infectious disease cultivated under certain detrimental conditions is attenuated in its pathogenic activity; from a virus it becomes a vaccine.

From that *first* conception, the rules developed which govern our present-day pasteurization, known and practiced in the ordinary life of households and industries the world over.

From the *second*, as we have said, Lister drew to completion his system of surgical antisepsis, puerperal fever was vanquished and child life saved and modern surgery made more nearly an exact science.

The *third* conception, upon which Pasteur based his antirabic serum, prevents hydrophobia and is the fundamental conception underlying all the achievements for tuberculosis, plague, malta fever, malaria, tetanus, cerebro-spinal fever. The work on epidemic infantile paralysis, the work of Metchnikoff on arteriosclerosis, of Ehrlich on syphilis, on leprosy, dysentery, sleeping sickness, have all been built upon the germ theory and the method of dealing with micro-organisms which Pasteur worked out. Diphtheria is now a preventable disease, its mortality reduced from 50 to 60 per cent. to 2 per cent. Mortality from rabies is less than 1 per cent.

Once in answering an attack upon his theory of fermentation, he said: "You wish to upset what you call my theory in order to defend another. Very well, let me tell you the signs by which a theory may be recognized as true. The characteristic of erroneous theories is that they can never produce new facts, and every time that a fact of this kind is discovered, these theories are obliged, in order to account for it, to graft a new hypothesis on to the old one. The characteristic of true theories is, on the contrary, to be the expression of actual facts, to be ruled and dominated by them, to be able to foretell new facts with certainty—in a word, the characteristic of these theories is their fertility."

We are glad Pasteur lived to see thousands of children saved by diphtheria antitoxin, and knowing the tender heart of the great man, it must have been the consolation of his feebler years. "When I see a child," he used to say, "he inspires me with two feelings, tenderness for what he is now—respect for what he may become hereafter." And so Louis Pasteur brought to medicine methods of research whose fertility knows as yet no limitation but time, the characteristic, as he said, of true theories. Modern sanitation, modern hygiene, modern preventive medicine are based fundamentally upon Pasteur's theories.

"He was not a doctor, he did not cure individuals, he only tried to cure humanity," was an explanation given of him by one who loved him. He brought more than method and proved theory to modern medicine, he brought the spirit of scientific investigation, the impersonal search for truth, a passion for service, an honest welcome to honest criticism. "Worship, the spirit of criticism," he said. "if reduced to itself, it is not an awakener of ideas or a stimulant to great things but without it, everything is fallible, it

always has the last word. When you believe you have found an important scientific fact, and are feverishly anxious to publish it, constrain yourself for days, weeks, years sometimes, fight yourself, try and ruin your own experiments and only proclaim your discovery after having exhausted all contrary hypothesis. But when, after so many efforts you have at last arrived at a certainty, your joy is one of the greatest which can be felt by a human soul."

In his last public address, he refers to himself as "a man whose invincible belief is that science and peace will triumph over ignorance and war, that nations will unite, not to destroy but to build and that the future will belong to those who will have done most for suffering humanity. But whether our efforts are or are not favored by life, let us be able to say, when we come near the great goal, 'I have done what I could.' "

In the quiet low-vaulted chapel at one end of the long corridors of the Pasteur Institute in Paris, Pasteur lies. Four great white angels guard his sleep, Faith, Hope, Love and Science As war once more devastated his beloved country and nations were once more united to destroy, one was glad that Louis Pasteur, who gave his life to constructive forces, was spared the agony of the struggle. And yet by his efforts the horrors of that struggle were lessened and the future still belonged to Louis Pasteur, who had done most for suffering humanity.

BOTANICAL FACILITIES IN PARIS

By Dr. ORAN RABER
UNIVERSITY OF WISCONSIN

THE time has passed when it was impossible for a man to obtain a place in a first-class American university without a European degree. Our equipment, our facilities for research and our scholars are not excelled in any of the institutions of Europe; and, although for a few special fields there may be exceptional attractions abroad, the American university has become of age. It is quite able to take care of itself freed from European tutelage.

As long as personality, however, has any influence in this world and until all parts of the earth become so similar in conventions and customs that travel will have lost its charm, there will be men who, in spite of the inducements of better laboratory facilities, in spite of the comparatively great wealth of our own universities, and in spite of the inconveniences of foreign languages and habits, will travel to distant lands to complete or supplement their education.

And this is as it should be. In the middle ages a certain amount of travel was considered indispensable to the training of the educated gentleman, and from that day to this there has been fostered this spirit of international exchange of ideas. The Great War for four years deterred the natural flow of student life and turned aside the stream into other channels. Soldiers instead of students formed the mass of the current and increased its dimensions many-fold. And now that the war is over and the world again is turning to the arts of peace, many of these same students, their interest awakened by the contacts made in the days of 1918, are planning to return and reexplore the countries in which they fought. This time they are going back with books instead of bayonets and scalpels instead of swords.

Because of the French connections made and interests aroused during the war, France in place of Germany will be the natural goal of this new army. Paris at the moment has more interest than Berlin. Furthermore, France has now made it possible for a foreigner to secure the doctorate, and those individuals who can not work without the stimulus of the Ph.D. or Sc.D. to lure them on can now find in France the way to satisfy their ambition.

All France is divided into two parts—Paris and the Provinces. While the provincial universities have facilities which in many cases equal those in the capital, the many-sided life of Paris is certain to attract every student there sooner or later, and, supposing, as we are in this case, that the student is a botanist, what and whom is he going to find there once he has arrived? What are the botanical facilities in Paris and who are the botanists that at the present time are directing the botanical life of the famous city? In the following pages it is attempted to summarize in a concise fashion the equipment, including libraries and herbaria, and to give the prospective student an idea of the personalities who are conducting the research laboratories, with a brief survey of the personal interests of the investigators in charge, the number of graduate students in the laboratories and as much as possible of the sort of information which one likes to know before entering any particular laboratory or institution.

The institutions of higher learning in Paris where research facilities are provided in Botany are École Normale, l'Institut Pasteur, Museum d'Histoire Naturelle and La Sorbonne or the University of Paris, with its Faculty of Pharmacy and Faculty of Science. It will be noted that the Collège de France is not in this list. It possesses no chair of botany and it is hence impossible to receive either botanical instruction or carry on botanical researches there.

Of these four institutions the Normal School and the Pasteur Institute may be considered together. Both research laboratories in botany are under the supervision of Professor Blaringhem. The teaching phases of the subject are handled at the Normal School, while the research work is conducted at the Institute. If any thesis prepared is submitted for a degree it is presented through Blaringhem to the Sorbonne, which awards the degree, since neither the Institute nor the Normal School have the power to grant the doctorate. Only a university can grant degrees, but other institutions can train research workers. The theses are examined by a committee of the Sorbonne in conjunction with the professors of the collaborating institution.

In addition to these two laboratories under the supervision of Blaringhem there is a field station at Bellevue, out ten kilometers from Paris, and a laboratory for the study of forestry and the acclimatization of trees at Angers. With these varied interests Professor Blaringhem is a busy man. He has a bit too much for one man to handle but, in spite of this handicap, students from America who wish to enter his laboratory will be very welcome. He is assisted by an instructor at the Normal School and has one

laboratory assistant at the Institute. There is also an assistant in charge at Bellevue. The time of all these assistants is at the disposal of graduate students.

During 1921–1922 there were three students working for the doctorate. One was working on some phase of physiology connected with plant breeding, a second on the cause of striped leaves and leaf spot, and the third on variations in the violets. These subjects are noted, since they may serve to the prospective student as a guide to the interests of the professor in charge. Blaringhem's special field is the study of heredity and variations.

The library at the Normal School is especially rich in books dealing with the cryptogams. The herbarium at the Normal School is not in good condition for research, but at the Institute there is a herbarium of about 60,000 sheets, covering France and the Mediterranean region. This herbarium is a selected one made for the purpose of showing variations.

Le Museum au Jardin des Plantes

The museum is not a teaching institution in the regular sense, since no courses are given which lead to diplomas or degrees, although there are many lectures open to the public, and free courses somewhat in the nature of our extension courses are given. It is open to every one free of charge. There are no degrees granted, and in this respect it is similar to the Pasteur Institute. Work completed there may be turned in as a thesis to the committee of the Sorbonne.

The activities of the museum correspond to the biological phases of the work done by the British Museum. In America we have nothing which corresponds to it, although the Smithsonian Institution and the Department of Agriculture at Washington are perhaps the nearest analogies. At the present time the building in which the botanical collections are housed is antiquated and inadequate. The laboratories are only fairly well lighted and the general facilities are poor. In the near future, however, a new building is to be built which will be more adequate to the demands of the collections.

In botany research is carried on in five different lines with a competent researcher in charge of each section. These men are Mangin, Bois, Costantin, LeCompte and Maquenne.

Professor Mangin, who is one of the six botanists in the Academy, is at the present time the director of the museum and at the same time is in charge of the research work in the Thallophytes and Bryophytes or cellular cryptogams. His special fields are the parasitic fungi and plankton. Foreigners are very welcome in his

laboratory and he will do everything possible to put before them the facilities of the museum. In his laboratory there are three assistants, which include the herbarium aides.

The library contains about 3,500 volumes on Algae and about 2,000 on the Fungi, including separates. There is a general herbarium and also several individual herbaria, coming from private collections, which make a very complete collection of Algae, Fungi and Bryophytes. The Algae collection is among the most complete in Europe.

Professor Bois has charge of the greenhouses and supervises the culture of the plants in the garden. He gives a public course on the culture of plants with especial reference to decorative species and also makes field trips. He was a student of deVries and it is not surprising that his special field is variation and heredity.

Professor Costantin is a member of the Academy and professor of morphology and paleobotany. His special field is organography and his principal researches have been on the effect of environment on plants and on the culture of Fungi.

In his laboratory he has one assistant and two preparateurs (a rank which corresponds to that of an instructor in a university) who assist him and any other workers present. At the present time he also has with him a Museum Fellow who is working upon the effect of Alpine climate upon floral structures. The library connected with this laboratory contains about 2,500 volumes.

Professor LeCompte is also a member of the Academy and is in charge of systematic botany with special reference to the vascular plants. The herbarium is the largest in France, as the following figures attest:

	Sheets.	Species.
Phanerogams	1,500,000	85,000
Vascular cryptogams	50,000	2,000

LeCompte gives all assistance possible to the many workers who arrive daily to consult the herbarium, and in addition the services of the seven assistants are at their disposal.

The chief researches of Professor LeCompte have been made upon the phloem of angiosperms, floral articulations and the woods of the French colonies. At present he is engaged upon the flora of Indo-China.

The library of systematic botany is very complete. There are 10,000 cards in the index, and in addition the cards of the other libraries of the museum are indexed in the systematic catalog. This figure includes the separates.

This laboratory collaborates very closely with that of Professor Costantin, in which latter laboratory the more characteristically morphological studies are made.

Professor Maquenne is in charge of physiology and is interested chiefly in the action of salts, respiration and the action of the ultra-violet rays. Professor Maquenne is a member of the Academy, but not of the botanical section. Because of the practical application of his work to agriculture he has been admitted to the section of applied sciences. Among the laboratories at the museum the writer recommends least that of Maquenne. As described below there are other laboratories in Paris open for researchers in physiology where foreign workers will receive a more cordial welcome. Furthermore, Professor Maquenne is growing old, and this fact, coupled with increasing deafness, detracts from the enthusiasm of the foreign student regardless of the excellent work which Professor Maquenne has done in the past.

The Sorbonne

Since the thirteenth century, when the University of Paris was founded, workers have been drawn from all over the civilized world to its laboratories and lecture halls. It is the most famous institution of higher learning in all France, and it is fitting that it should here be reserved for the end of these brief remarks.

There are two "faculties" or colleges in which botanical training is given, *viz.*, the college of pharmacy and the college of science. The School of Pharmacy is a purely professional school, and the work taken in course leads to the degree of doctor of pharmacy. By special arrangement, however, it is possible for a graduate student to do research in the laboratories of this school and take the degree of doctor of science.

Professor Guignard has charge of the work in phanerogams and finds little time for the supervision of research students. He would accept American research students only by previous arrangement, so that it would not be advisable for a student to make plans for entering his laboratory without going into the matter thoroughly in advance.

Guignard is a member of the Academy and is known best for his work on nuclear division, embryology of the leguminosae, and double fecundation. His recent researches are being done on the localization of the active principles in plants.

The library of the School of Pharmacy is very well organized and is especially complete in chemistry. The student will also find, however, that the better known American botanical publications such as *Botanical Abstracts, Botanical Gazette,* etc., can be more easily found and consulted in this library than at the main library. The herbarium is particularly rich in the phanerogams of France. There are about 100,000 sheets, comprising 75,000 species.

Professor Rades is in charge of the laboratory of cryptogamic botany, but this term is rather a misnomer since the work is largely medical bacteriology. His principal research has been done on the mycoses. His laboratory contains one assistant, and this past year there was one student working for the degree of doctor of pharmacy.

The library contains about a thousand titles on cryptogamic botany and bacteriology. The herbarium is not of much value, but a fairly good collection of pathogenic strains of bacteria is kept running. An American in Paris, however, had better spend his time at the Pasteur Institute if he is working in this field. At the institute he will find much better equipment and more congenial surroundings.

The College of Science

Among the botanists at the University of Paris probably the best known, although undeservedly so, is Bonnier, professor of general botany. While he has published various papers on respiration, assimilation and experimental morphology, and although he is a member of the Academy and editor of the *Révue Générale de Botanique*, it is very difficult after seeing the way in which his laboratory is at present conducted to understand how he has gained the eminent place he has held. True, he was the son-in-law of Van Tieghem, and that in the minds of many French botanists explains much.

Professor Bonnier is also the director of the laboratory at Fontainebleau, which is located out 55 kilometers from Paris in the famous forest of the same name. This laboratory is one of the very few field laboratories of the world devoted exclusively to botanical research. Located, as it is, in the great forest, it is hard to imagine a place where botanical research could be carried on under a more favorable environment. The laboratory is well lighted and well equipped, so that, in spite of the personality of Bonnier,[1] work there is a genuine delight. The director in charge is Dr. DuFour, a mycologist of long experience and a man who knows the fungi of France as well as any man in Europe. Dr. DuFour adds immeasurably to the charm of a sojourn in Fontainebleau, and it is impossible for one to quit this laboratory without feeling a very personal debt for the many kindnesses he is sure to receive at the hands of this amiable gentleman.

During 1920 and 1921 there were 24 research workers at the laboratories in Paris and in Fontainebleau. Four students re-

[1] The death of Bonnier in Dec. 1922 was reported after (*post non propter*) this article was prepared.—O. R.

ceived their doctorates and ten others were engaged on theses which they intended to present for the degree. The remaining ten were stray workers who were at Fontainebleau or Paris in connection with some special private problem. The four theses presented were on the anatomy of the liliaceous flower, the morphology of the Marchantiaceae, researches on the Frankeniaceae and the Euphorbias of Madagascar.

The herbarium of the Sorbonne is largely of French flora. Among the phanerogams there are about 18,000 sheets with 6,500 species. The cryptogams are represented by about 2,000 sheets covering 1,200 species. This is not a large herbarium, but, as mentioned above, all workers have the use of the museum collections. The library is poorly organized.

Dangeard, the well-known cytologist and Academician, is also at the University of Paris He gives the courses in elementary botany for the pre-medical students and conducts a private laboratory of research near the Jardin des Plantes. Unfortunately his laboratory is not open officially for research students without special arrangement. This is a university regulation and not strictly in accordance with the wishes of Professor Dangeard, who would welcome to his laboratory American students of the proper training and give them all the supervision and advice possible. His laboratory will not hold more than two students because of lack of space and equipment, and it would hence be best to make arrangements in advance. However, if any student is going to France to study cytology he will nowhere find a more cordial welcome than with Dangeard, and if there is any way in which he can be accommodated he will find nobody more willing to help him.

Dangeard's principal researches have been in the fields of protistology, reproduction in the fungi, and in the field of anatomy and cytology. He is director of *Le Botaniste,* now in its fourteenth series. He is assisted by his son, who works in the same laboratory and who has also made several contributions to botanical science.

Aside from Bonnier's laboratory of research at the Sorbonne there is that of Molliard, professor of plant physiology and dean of the Faculty of Science. Molliard's chief researches have been made on the morphogenic action of various organic substances on the higher plants, the production of citric acid by *Aspergillus niger*, and the physiology of plant galls. At the present time he is working on an eight-volume text of plant physiology. Two volumes have already appeared and give promise of a work truly monumental. This is the most complete work on plant physiology which has appeared since the well-known German texts and deserves wider attention than it has thus far received in this country.

In Molliard's laboratory there are six assistants and instructors, two of whom are working on the doctorate, their theses being "The action of acids on the composition of plant ash" and "The effect of acidity on the formation of organic acids in the higher plants."

While this laboratory is better equipped for researches in plant chemistry than for those in plant physics, the worker will find Professor Molliard as generous with funds as conditions permit, and any necessary apparatus can always be secured. For the plant physiologist in Paris there is no laboratory which offers as many attractions as this and none where the researcher from America will be more cordially given a place.

This completes our list of facilities in Paris And what is the conclusion? Simply this: Go to Paris without anticipating the splendid buildings and the abundance of equipment which characterize many of our American universities. However, for everything you miss you will find somewhere something to take its place, and what one loses in external facilities he gains in increased initiative and independence. And, moreover, no American should study botany too hard when he is in Paris

THE STUDY OF LIFE AS A THING WORTH DOING

A Suggestion for Undergraduate Students

By ALBERT L. BARROWS
NATIONAL RESEARCH COUNCIL

YEARS ago when I was in college I had a teacher of biology who had become a national authority on bees. He was very fond of them. He had gone on from that earlier achievement to studies of other useful insects and to studies of insect pests of crops. He knew a great deal about them. He spent much of his time going about the state showing farmers and orchardists that a thorough knowledge of these things could be of great importance to them—that is, that biology was of practical value in agriculture. But what he labored to show his students in addition to this was the wonderful way in which this strange thing which we call life works. He tried to paint a picture of this life force in the structure and physiology of an individual animal or plant and the way in which this force has passed itself on from age to age through countless kinds of animals and plants. How this came about was to him the all-absorbing problem. This same problem is one of the questions which men have pondered over ever since the earliest peoples first conceived their ancient beliefs of whence we have come and whither we are going and pictured their ideas on skins and bones or carved them upon the rocks.

Dr. Raymond Pearl has recently described this problem by asking some simple questions: How many kinds of animals and plants are there? How did there come to be so many kinds? And why is it possible for living things to be here on the earth, any way? What is it which makes a living thing so much more wonderful than a rock or the air or a rain-drop? Every one at some time has asked himself these questions in one form or another. Why are we here? Why do we do as we do? Why are all the other animals and the plants here? What are the conditions which make possible this curious phenomenon which we call life, partly chemical, partly physical, partly something else—perhaps? How long did the world have to wait after it was cast off from the sun and while it was cooling down before this puzzling activity of life could be developed, an activity in which certain combinations of the elements

organize themselves into little chemical engines which we call cells and which react to changes in their surroundings, take in food material and grow and finally reproduce other cells and organisms just like or nearly like themselves? This is what living things do and what makes them different from inanimate things. And we should all like to know how it comes about.

This old professor of mine taught us first how to recognize some of the kinds of animals and plants of our region, and how to see exactly those differences which count in making them different. He gave us one day a book to read about the "Origin of Species," the significance of which I am frank to say none of us came near grasping until many years later. But we did gain from this book some idea of the agelong process of development of the varied forms of life, of certain relationships between them and a suggestion as to how it all might have happened. We got the idea, too, that animals and plants have not always been the same, that life is constantly changing, and we gained some conception of the principle of progressive change which we call evolution.

Later I learned something of the wonderful work of Pasteur, who was finally able to show—and not so very many years ago, either—that, at least as things are now, all living beings come from previous living beings, and that there seems no longer to be any such process as the spontaneous generation of life, that conditions must have changed since life first began, that life has gotten its start and is now on its way—on its way toward what?

Life was a very wonderful problem to this teacher of mine, one which seemed to him to be at the bottom of many other problems which we should like to solve in regard to the uses which can be made of animals and plants about us, in connection with the troubles which some of them—the smallest of them—cause us, and finally in the explanation of the histories of peoples and their customs and our own social relationships and activities to-day. He made us feel that one of the most important things a college graduate can do is to study these questions and perhaps make some contribution toward their solution, and add to human welfare thereby, or help to gain a better perspective of the place of man in this universe, so important a place to us, so insignificant to the sun, the moon and the stars.

Some years later other teachers made me acquainted with the clue which Gregor Mendel hit upon, scarcely realizing it himself, as to another possible cause for the course of development of living things, through the operation of the laws of heredity. The present generation of biologists is following up this clue and is trying to find out just how the differences from the average stock are handed

on from one generation to the next. What changes are handed on and what are not? What are the rules under which these changes are combined and re-combined in one generation after another with a variety limited only by ability to get along with the surroundings? How much does habit or the environment have to do any way in stimulating these changes? How much is due to new combinations of characters or interbreeding? How can man take advantage of all this in improving this stock of domesticated animals and plants?

I had also a teacher who, from studying the animals of long ago, had made himself their historian. He told me parts of the wonderful story of animals and plants in the rocks, the successive strata of which are as truly as anything can be the leaves of a great book, showing, if one has but the patience to decipher the record, the changes from one animal or plant form to another and the changes of groups of animals and plants from place to place and from time to time, beginning with the oldest rocks formed by the wearing down of the first hardened earth surface by the washings of the earliest rains into the original seas. This paleontologic record or history of animals gave another clue as to how the scale of life has grown and as to its enormous extent.

My later teachers told me something also about the strange conditions of life in the sea, so different a world from that of the land, but touching right at our very shores. They showed me how all these animals and plants of the sea, feeding upon one another, depend finally upon the myriads of minute plant and animal forms which make up what have been called "the meadows of the sea," flaring up as spring and autumn "crops," and providing the basic organic stuff upon which the larger organisms of the sea survive. One can not help regarding this vast assemblage, with the sea itself, almost as another huge pulsating organism. This gave a clue as to the kind of environment in which the life processes of our world may have started—for there must have been a beginning somewhere.

From another of my teachers I got another suggestion for the unravelling of a part of this riddle of life through the study of the Protozoa, the smallest and the most primitive of the organisms in the animal series, some of which seem to be as close to the first animals as any organisms on earth to-day. This group contains those which seem to bridge the gap between the animals and the plants, the one essential difference between these two great modes of life being that animals can live only on stuff which has already been made up by other living things into substances organized to contain the spark of life, while plants can take their food from the raw

elements. Some Protozoa appear to do both. Nothing, except perhaps the bacteria, has ever seemed to me to show the three functions of living matter—sensibility, feeding and reproduction—more graphically than the Protozoa, in which a single cell carries out the whole life story. Hundreds may come within a single field of view at the bottom of a microscope tube, scurrying ever after food, multiplying at an enormous rate. How is it that from these tiny creatures the force of life has built up the complex organisms all around us with larger and much more complicated bodies? What stimulated the development of the organs of special sense, not only those of touch but those for perceiving light, sound and odors and tastes, from a blind groping among the simplest animals to keen and highly perfected organs which the birds, the forest wolves and cats and we ourselves enjoy? How much development was necessary before animals could become conscious of themselves? What makes the human animals at the latest end of the series concern themselves over their relations to each other, establish laws and form nations, seize the raw materials of the earth and fashion them for their own uses, and begin to reflect upon the principles according to which this has all come about and what it is all leading toward? Is this long chain of related organisms existing only to perpetuate itself in more and more intricate forms, like some other organizations that we know of, created by their founders largely to give the members something to do in running them? It is a long, long story, and the man must have zoological training who would make any contribution to a real solution.

All these questions are, after all, only different ways of putting the fundamental inquiries of how there come to be so many different kinds of animals and plants and what makes them "go." What is this principle of progressive change which we call evolution, a relating of present forms of life to previously existing forms perhaps now extinct, a connecting of current events to those of the past? The astronomer revels in ideas about it, the chemist and the physicist see it in the behavior of the atoms of the elements, the geologist has it always before him in the constant working over and over of the materials of the earth's surface, the historian is the recorder of it in human affairs. But, universal as this principle is, there is no other material than the succession of animals and plants in which the principles of evolution are better and more readily illustrated, though the evolution of life is only one phase of this all-pervading process. It is the special privilege of the biologist to unfold its mysteries as applied to living things.

The biologist goes about answering these questions in many ways and a little part at a time. The man who counts and de-

scribes the different kinds of animals and plants makes perhaps the first contribution. The man makes his contribution also who observes their minute differences or variations, and who studies the results of sorting and cross-breeding. The man who studies animals out-of-doors, their habits, behavior and the ways in which the climate, hot or cold, wet or dry, and the surroundings of plain or forest seem to have affected them, makes his contribution. The microscopist who works out the complexities of the chromosomes of the sex cells adds his part

And the man who thinks that he is engaged wholly in the practical side of zoology has always at his hand material for the study of these deeper, most fundamental questions. The physician and surgeon are the appliers of highly refined zoological attainments, whether in the history of protozoan and vermian parasites, the theories of epidemics, the development of serums and the underlying theories of susceptibility and immunology, the problems of cancer, the running down and control of the causes of one disease after another, and the conception of the human body as a complete but delicately balanced mechanism furnishing to a certain extent its own protection against disease and its own stimulants and correctives. The progress of medicine is fundamentally a biological matter, whether the subject of study be the human body itself and the functioning of its parts or the organisms which may infest and destroy it. The man who takes up research in medicine has before him one of the largest of the opportunities for service and for strengthening man's control of this world.

Every farmer, too, is a biologist of a sort and there is a greater and greater demand for more complete knowledge of farm animals and plants to be applied to his uses The farmer wants his breeds of animals improved and stabilized. He wants them protected from disease. He wants the state entomologist to pit his ingenuity against the vital impetus for reproduction in the enormous numbers of insects which are ready to destroy his crops or wants him to take advantage of other insects which can be made useful in a war upon their own kind. He wants to know why differences in soils affect his crops and what are likely to be the long time results from fertilization and from irrigation in producing better crops, together with the liability that new insect hordes may attack them under these artificial conditions.

It is only comparatively recently that we have realized that the wild animals which we have preyed upon for food and leather and furs must be protected against extinction, and that these natural resources can be actually increased by wise control based upon a sound knowledge of the biology of these animals. The conserva-

tion of game for the recreation of hunting and fishing, the preservation of the fur seal herds and of the salmon, cod, herring and oyster fisheries are all problems for the practical zoologist. We can offer ourselves no excuse if we do not take the means which investigation is sure to show to keep these great natural resources productive. These are some of the questions now open for zoological research.

There are many opportunities for engaging in such investigations as these, whether in connection with teaching or in connection with the application of zoology to medicine, agriculture, fisheries or other industries. But a research position is no place for the man who wants merely to make money nor for the man who, despite his college education, is likely to find difficulty in holding his own in any profession. Research work calls to the most able students, those who have sufficient natural ability to be sure of a living in whatever they undertake and who can devote their main interests to the larger purposes of their work. Zoological, or one might better say, perhaps, biological research, appeals to those whose fundamental interest is really in the problem of life. Into this work must be combined the experience of the chemist and the physicist, the lore of the geologist, and the training of the mathematician and something more—the observations peculiar to the special study of living things.

Above all, a research career calls to men who crave to know the unknown. It demands a spirit of adventure, a willingness to pioneer upon the frontier of present knowledge, an imagination to be able to guess, and guess correctly, the meaning of what is learned, and an ability to lead in thought out beyond that which is already understood, to wrest from the beyond new facts and new ideas, to deal with uncertainties, probabilities and sources of error, until one can find a treasure of fact which will make the uncertain sure and the incomplete more nearly complete.

Zoological research has not only contributed in important ways to our physical well-being and prosperity, but in contributing to our knowledge of why any living beings are here, the life sciences lay the basis for attacking the eternal problem of why in the endlessly rolling processes of this enormous inanimate universe there should occur a brief stage under certain nicely balanced conditions when a few select materials may organize themselves into a succession of beings which eventually become aware of their surroundings and then of themselves, and in their highest examples finally acquire a considerable power for self-direction and manipulation of the materials around them.

No zoologist ought to enter upon his researches without at least an occasional thought to this ultimate question. And no student should allow himself to be drawn into this impelling course of life-long study who has not analyzed himself to make sure that he has the requisite qualifications, nor unless he is unable to resist a consuming desire to know more of the riddle of life, at once the most interesting and perhaps the most baffling of the problems on which we can now engage. But there is a solid satisfaction in store for the zoological investigator in the successful development of his students, if he is a teacher, and in the contributions which he can make to knowledge in the application of this knowledge to human welfare, and in the consciousness that he is engaged upon a study of the fundamental problem of life and of the development of the life process to the human stage in which we can undertake an examination of this life and of its position in the general scheme of things.

A FISHER OF MEN AND MINNOWS

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

IN one sense, we doubtless exaggerate the importance of our "great men." Once a man becomes a national figure it is possible to write or converse about him without having to explain who he is. Let him utter platitudes, and they are quoted as gems of wisdom, partly because they confirm from a high source the commonplace ideas of the multitude. Those who publish their recollections are proud to recall every contact with persons sufficiently famous or infamous, but have little to say about those who may have meant more to them, but remained unknown to the great public. Indeed, to have a "name" is a commercial asset, and in these modern days we have the spectacle of numerous persons conspiring to confer distinction on the incompetent and vicious. The public is perhaps only partially deceived, but it has no sufficient standards of its own, and is willing to give its attention to anything which is forced upon it. Even street songs acquire tremendous vogue almost regardless of their meaning or literary values. Mimicry is, after all, the cheapest form of expression.

Reflecting on these things, it is possible to grow pessimistic, and thereby to overlook the very springs of human progress. New movements and new ideas originate with individuals, and the intellectual work of the world is carried on comparatively few shoulders. Put aside entirely the question of "distinction," and ask how many, exactly, are carrying forward a certain line of endeavor. The answer will astonish those who have not considered the matter. There are numerous really important branches of science to which contributions are being made in the whole of America by less than a dozen persons. In a population of a hundred millions the productive scientific group numbers only a few thousands, yet its work affects us all every day of our lives. Regarding things in this manner, we are dealing with objective facts, and no question can remain concerning their validity.

In the fields of education and public policy, our judgments can not be so definite, if only because the work is far less individual. The very fact of social leadership implies a certain lack of originality, a disposition to join with others for a common end. Yet in the

midst of the confusing cross-currents of human affairs, the man who can orient the forces of society to produce a purposeful flow is a benefactor of a very high type. History will truly record that for certain important purposes he was indispensable. With the passage of time and in the light of subsequent events, it is possible to distinguish between functional significance and mere notoriety.

The newly published autobiography of David Starr Jordan[1] records seventy years of the life of one who showed an extraordinary capacity for work and leadership in the fields of science, education and public affairs It will be read by many who have known Dr. Jordan, or have had some part in the movements in which he was the leading figure Vernon Kellogg, writing in *Science*, has well expressed the attitude of such readers, to whom the subject is too near and dear to permit of cold analysis. A larger public, and particularly those of later generations, will find in the story an illustration of the higher possibilities of American civilization, worthy to be studied by those who wish to see a better world. The scientific student, interested in social phenomena, will try to distinguish the effects of heredity and environment, asking exactly what we mean when we describe Dr. Jordan as a characteristically American product.

Since our subject is unique amongst so many millions, it is easy to affirm that inborn capacity sufficiently explains the phenomenon Yet this capacity developed along the lines of opportunity, and no one can study the life without perceiving that the total result depended upon a vast number of circumstances, trivial or otherwise. Certainly no human being has ever attained his maximum potential efficiency, because a perfectly suitable environment has never existed. Simpler organisms may sometimes do this, but our life is so complex and so full of chances for error and failure that we must marvel at even moderate success Unless society can be organized on a better basis, the proportion of failures, partial or complete, may increase until life is hardly worth living for the majority. It is this evil consummation that we must prevent by using whatever wit and good will we may possess. The contemplation of Dr. Jordan's life, representing a very high degree of success in utilizing the gifts of heredity, should at least give us useful hints, aiding our efforts to promote like results in the future.

We get the impression of the wholesomeness of American rural life in the fifties and sixties of the last century It combined a certain simplicity with reasonable educational facilities; free from the feverish excitements of metropolitan life, and yet lifted far

[1] "The Days of a Man" (two volumes), World Book Company, Yonkers-on-Hudson, N. Y., 1922.

above the trough of dull-witted ignorance in which the country population of England was largely submerged. Good books were available and the idealism of the period reached many out-of-the-way places. The older folks had, in general, struggled successfully with the forces of nature, and knew where real wealth came from. Without pretending that conditions were ideal, we may recognize that there were elements of greatness diffused through the social organism, ready to come to a focus when meeting with capacity. No rigid political or economic doctrine can adequately explain such a situation; it is almost as subtle as personality, and similarly potent.

In his eighth or ninth year, Jordan had a wonderful trip with his parents Taking a horse and buggy, with a little stool for the boy, they drove fifty miles to Irondequoit, near Rochester, on Lake Ontario They then went 25 miles to Albion in Orleans county, every mile of the way full of new wonders for the child "That trip to Rochester stands out in my memory as a sudden disclosure of the great world which I have ever since tried to explore and understand" But, adds Dr. Jordan, an automobile would now cover the entire round trip in five hours Cover it, no doubt, but the old-time horse and buggy uncovered it, in all its glorious details, to the astonished gaze of the future naturalist

Home influences were wholly salutary. Jordan's parents left the Baptist church because they could not accept the then prevalent doctrine of "infant damnation." The boy was surrounded by "strong religious influences untouched by conventional orthodoxy." The parents had "the Puritan conscience, and were very rigid as to personal conduct, deprecating all forms of idleness and dissipation generally." Tobacco and alcohol were not used, and cards were regarded as a waste of valuable time. A minister, Mr. J. L Jenkins, took young Jordan on geological excursions, and awakened a strong interest "in the make-up of the earth." He urged the parents to send him to college, though at first there was some hesitation. In 1869 Cornell University, recently founded, offered free scholarships, and in the competition for one of these, Jordan was successful. He accordingly went to Ithaca, with only 75 dollars in his pocket, "but rich in hope and ambitions."

At Cornell he earned his living in a variety of ways, and boarded at a club known as "The Struggle for Existence," generally abbreviated to "The Strug." While still an undergraduate, he was made instructor in botany. Several of his college friends were interested in various phases of natural history, and have since become well known from their work. Thus Jordan rapidly developed into a trained naturalist, but the beginnings both of his in-

terest and of the moral stability which led to success long antedated entrance to college. Cornell, however, was an inspiring place, and after the lapse of years, he has this to say about it:

> The early days of my Alma Mater, though relatively crude and cramped, were enriched by an enthusiasm hard to maintain in days of prosperity. And the pioneer impulse far outweighed, to our minds, any deficiency in coordination, equipment or tradition. At that time we were all young together, freshman students, freshman professors, freshman presidents without experience or tradition to guide or impede. But we had youth and we had truth, and not even the gods have those!

After graduation came opportunities for teaching, and the beginning of leadership in scientific activities. Evidently Jordan would have been a leader of men under almost any circumstances, but it is no small matter that he chose the lines he did, and this must be ascribed mainly to the influences and opportunities which came to him. Furthermore, the relative freedom of American educational institutions gave him his chance, and all things considered he met with far more support than opposition in developing genuinely liberal and scientific culture. The summer with Agassiz at Penikese made an indelible impression, and is thus epitomized:

> So the summer went on through a succession of joyous mornings, beautiful days and calm nights, with the master always present, always ready to help and encourage, and the contagious enthusiasm which surrounded him like an atmosphere never lacking. A born optimist, his strength lay largely in a realization of the value of the present moment. He was a living illustration of Thoreau's aphorism that "there is no hope for you unless the bit of sod under your feet is the sweetest in this world—in any world."

This, we remember, at the very end of Agassiz's life, spent in high endeavor. Jordan expected to be a botanist, but took up fishes because they seemed to offer better opportunities for research. It is probable that he had a special, inborn capacity for biology, but certain that he might as well have been a botanist, ornithologist, entomologist or conchologist as ichthyologist. Agassiz's influence was probably a deciding factor, and we can say now that no better line of work could have been chosen. The magnitude of Jordan's ichthyological labors (by no means finished) can not be readily estimated with accuracy, but few zoologists have covered more ground or made more discoveries. A mere catalogue of the new facts brought to light would not suffice, as it would leave out of account the gigantic labors of setting in order the fish faunas of North America, of the Hawaiian Islands and Japan. The details of the work may be criticized, and posterity will propose changes in the system, but the truly pioneer work has been done once for all. Very recently, Dr. Jordan has published

a bibliographical work covering all known generic names of recent and fossil fishes, which will be an indispensable handbook for all future workers.

On the first of January, 1885, Jordan became president of Indiana University, which at that time had only 135 students of collegiate rank He had not wished to assume executive duties, expecting to devote his life entirely to natural history and exploration. He was thus chosen, against his will, because his capacity for leadership and clear ideals for education had already become abundantly manifest. It is greatly to the credit of the trustees, and the people of Indiana in general, that they were anxious and willing to take a man with a thoroughly modern outlook, who knew what he wanted and would not be driven by the winds of transient opinion or led by the lure of political opportunity. Dr Evermann, referring to Jordan's work in Indiana, said (1916) "the influence upon the state was epoch-making"

Of Jordan's methods in Indiana it may suffice to say that they were inspired by democratic ideals, without being subservient to public opinion He sought successfully to create an enlightened public opinion by going everywhere, making speeches and getting in touch with leaders in local and state affairs. Later, in California, he did the same thing. Political methods, if you like, but methods which ultimately affected the thought of great masses of people and made it possible to give every competent young person a chance for higher education. With all this, he did not abandon research on fishes, and one wonders how he found enough hours in the day to do his work.

When Mr. and Mrs. Stanford planned to found a university in memory of their son, they sought out Jordan of Indiana as the man who seemed most competent to carry out their wishes. Their point of view had been strongly influenced by Agassiz, for whom they had a respect almost amounting to veneration. Thus it happened that once again liberal and progressive opinions triumphed, and the door of opportunity stood open. What came of it all is a matter of recent history.

Assuming, as we may assume, that people with capacities similar to Jordan's are not unfrequently born in this wide land, how can they be fully utilized? Are conditions now as favorable as they were during Jordan's period of development? Superficially they appear to be more favorable, at least in a number of respects. Whereas the struggle for adequate opportunity was formerly severe, we now thrust advantages before the student. Fine laboratories, great libraries, all are his to use to the utmost. Agricultural colleges provide for the sons and daughters of farmers; normal

schools are everywhere training teachers according to approved methods. In the natural sciences, the work is much better organized than ever before. Most groups of animals and plants have been intensively studied, and splendid monographs abound. Museums, filled with priceless treasures, have developed in various parts of the country Are we not in all respects most fortunate?

Yet, in spite of all these advantages, things are somehow wrong A recent visitor from England remarked on the fact that scientific men appear to have less prestige in America than in Britain. The sort of life and the ideals which irresistibly attracted young Jordan are perhaps losing their charm Agassiz could not do now, were he with us, what he did fifty years and more ago. In spite of our schools and colleges, and the growing number of university graduates, scientific research is poorly supported, and even when accomplished can only be published with great difficulty. Much of the literature sent out to arouse interest in the great schools (not excepting Stanford) gives one the impression that they are sporting clubs first and educational institutions second. When the alumni get together, it is usually to talk about athletics, or to witness a game. The people seek continual amusement, as though the personal activities of real life had lost their meaning The degradation of the arts has gone to a point which could hardly have been imagined fifty years ago The stupidities of the Victorian era were rather due to special conventions or limitations than to the abandonment of all desire for accuracy or beauty. The developing world-civilization, which we thought would make wars impossible, actually produced the most terrible and barbarous conflict yet known.

Must we then say, as we put down Jordan's book, It never can happen again? If we are resolved not to believe that, it is necessary to get a changed point of view. The president of Antioch College, in my hearing, recently said two things which have lingered in my mind. Asked whether he considered the arrangements at Antioch final, he said, "No, it is an experiment, and I hope it will always be conducted in that spirit." Asked whether Antioch was, like other schools, unduly dominated by competitive athletics, he said, "No, because real work compels amusements to take their proper place." The spirit of scientific work is experiment guided by experience, and thus it stands ever on the fringe of knowledge inspired by hope and expectation. The educational process should have a similar motive, for the morrow of every day promises something beyond. Defects in our economic and political systems, bad as they may be, do not account for the modern state of mind, nor are our young people intrinsically inferior to those of other days.

It has been justly remarked that the sources of modern degradation are, broadly speaking, not with the young at all, but due to the dominance of an actual minority of middle-aged or elderly people.[2] The young, on the whole, mean well enough, but are as sheep without a shepherd. Jordan thought Cornell, in the early days, owed its virtue to the spirit of youth. Again at Indiana, rapidly developing from small beginnings, was the bright spirit of adventure, free from pessimism or cynicism. So again at Stanford; say what you will, Stanford to-day is not what it was. The young, given a fair chance, will respond to ideals of virtue and beauty, but they will not create them unaided. They will not maintain them without adequate leadership. Leadership implies social sanction, which itself was developed originally through the efforts of individuals. Actually, we are moving forward, and many encouraging tendencies may be observed, but we need to find our Jordans and then give them a chance to act.

[2] If any one doubts the possibility of this, let him consider how fashions in dress are controlled by a small minority for commercial purposes and imposed with ease upon a pliant and mimetic public. They are not necessarily bad; occasionally they are beautiful, but sensible or absurd, beautiful or ugly, the success of the propaganda is the same. On the other hand, the pictorial side of commercial advertising, which depends for its success on genuine realism, can not afford to do without artistic skill, and often maintains a remarkably high level of excellence. The degeneration of art and literature comes about when sincerity of purpose has departed.

STANDARDS OF LIVING AS THEY AFFECT THE GROWTH OF COMPETING POPULATION GROUPS

By Dr. WARREN S. THOMPSON
MIAMI UNIVERSITY

In the growth of population in competing groups, under present conditions, there seems to be a law at work somewhat analogous to Gresham's law regarding the effects of competition between different types of money. It may be stated thus: *When groups of people (races, nationalities, classes) having different standards of living come into competition that group having the lower standards tends to displace and supplant the group or groups having higher standards* The phrase "come into competition" is used here to signify any situation in which groups find themselves pitted against each other in their daily efforts to make a living.

The proof that groups with lower standards of living displace and supplant those having higher standards is to be found by studying population growth in those parts of the world where competition between such groups is going on.

The Competition between Nationalities

Probably no portion of the world offers clearer illustration of these processes than the eastern and southeastern fringe of Central Europe. Of this region an eminent authority says:

> Another striking fact . . . is that the lower cultural groups are, at least temporarily, pushing back those of the higher cultural levels. The Pole of Posen is pushing back the Prussian, the Ruthenian is pushing back the Pole in Galicia, the Lithuanian is beginning to make headway against the Pole also at another point, and the Italian in Austria is pushing back the German. Naturally the isolated individual tends to be absorbed by the larger groups, and the question of the expansion of the populations of the lower cultural levels is largely a matter of the birth-rate and of the standard of living. . . .

In Posen the Poles have long had a higher birth-rate and a larger natural increase than the Prussians. In the decade 1871–80 the birth-rate in Posen was 46.2, while in Prussia (including Posen) it was 40.7. The rates of natural increase at this time were 16.2 and 12.5, respectively. In 1913 the birth-rate in Posen was 34.4, in Prussia 29.1 and the rates of natural increase were 17.1 and 13.3, respectively. Thus we see that the rates of natural increase in Posen are considerably higher than in Prussia. Because of this the

Poles steadily pushed westward into German territory and the German statesmen were alarmed at the supplanting of the Germans by the Poles. Bismarck, who was the author of the policy of forcible Germanization, said he was not afraid of the Polish man, but of the Polish woman because she was so prolific. He is credited with saying that the Poles multiplied like rabbits, while the Germans only multiplied like hares

We are not here specially concerned with the social effects of the policy of forcible Germanization of the Poles, but it is interesting to note that in so far as it placed the Poles under economic and cultural disabilities and thus kept their standards of living low it defeated its own aim by keeping the birth-rate and the rate of natural increase high. Because of this rapid increase of the Poles the spread of German culture was checked and the tendency was for the Germans in Posen to be Polonized rather than for the Poles to be Germanized.

The same process has been going on in Hungary, where Slovaks, Roumanians and other nationalities are in contact with the Magyars. Mr. Seton-Watson sums up the situation as follows:

> In the thirty years preceding the last census (1870–1900) the Magyars have gained 261 communes, but lost no fewer than 456 (a net loss of 195): while the Roumanians, though they lost 42 communes to the Magyars and 22 to other races, have gained 362 communes (a net gain of 298) The Slovaks have gained 56 communes from the Magyars, but lost to them 89 others; but they have made good this loss by a net gain of 175 communes at the expense of the Ruthenes Meanwhile, the genuine Magyar population is beginning to lose ground; emigration has thinned its ranks, and in recent years the "two-child system" has made alarming strides, especially among the peasantry of Baranya and Vos.

That this process of displacement of the Magyars by nationalities of lower culture is going on receives confirmation from a comparison of the vital statistics of Hungary and Roumania. The natural increase of Hungary for a number of years before the war held at about 11.0, while in Roumania it varied from 13.0 to 17.5, generally being 14.0 or 15.0.

There is little doubt that much of the chauvinism of the Hungarians, manifested in their attitudes toward their subject nationalities, grew out of their very real fear of being supplanted by the more prolific stocks by whom they were surrounded. As in the case of Prussia, the repressive measures taken to bring about Magyarization only served to arouse the nationalistic spirit in the subject groups and to keep the birth-rate high by placing them under certain economic and cultural disabilities.

There is no need to multiply examples of localities in which the struggle of nationalities for expansion is being decided by the abil-

ity of one nationality to live more cheaply than its neighbor. It is a process whose existence is generally recognized by those who have given some little study to the conflict of nationalities in modern Europe.

THE COMPETITION BETWEEN RACES

In the United States the white and negro races have never really "come into competition" within the meaning of that phrase as defined above. They have lived in different spheres of life. Consequently, the much more rapid rate of increase of the whites (16 per cent, of which about three fourths is natural increase, as against 6.5 per cent) is not to be regarded as disproof of the general thesis stated at the beginning of this article, but rather as the failure of a "primitive" race to make satisfactory adjustments to the civilization of a more developed race In the case of the Japanese in California, where there is no question of a "primitive" race involved, we have the beginning of a real competition. Of the native white women in California 20 to 49 years of age only 6.7 per cent. reported births during the year 1920, while 27.1 per cent. of the colored women other than negroes of the same age group reported births. A considerable proportion of these "other colored" are Japanese. When all due allowance is made for the tendency of many Californians to exaggerate and misinterpret the facts, we must still conclude that the rate of increase of the Japanese is much greater than that of the whites. The effects of this are seen in their efforts aiming at the expansion of the colonies already established and their desire to acquire lands to establish new settlements.

It is the feeling that white men have little or no chance to survive in competition with the Japanese that lies at the basis of the agitation against their immigration into Australia and Canada and into our own western states. Of course, what is called "race prejudice" enters into the account, but "race prejudice," in large measure, consists in antagonism aroused by differences in the modes of living of different groups.

The fact that the Japanese have excluded the Chinese and Koreans (the latter the inhabitants of one of their colonies) from certain occupations in Japan shows that they have this same feeling with regard to immigrants who are willing to work harder and live on less than they themselves are.

An experienced observer of the far east, Mr. J. O. P. Bland, frequently mentions the inability of other races, but particularly the white race, to compete with the Chinese. Along the Manchurian railway the Russian is not holding his own against the Chinese. He is soon found in the lower economic positions and he

must retreat or die out because he can not live as cheaply as the Chinese coolie with whom he has to compete. The Chinese can not be excluded from this area as we are able to exclude them from America because the frontier is a land frontier.

THE COMPETITION BETWEEN CLASSES

When classes of people of the same nation come into competition, the classes with the lower standards of living supplant the classes with the higher standards in the same way that nationalities and races with lower standards of living supplant those having higher standards. About 25 years ago (1897) J. Bertillon presented data showing that in the largest cities of Europe there was a progressive decrease in number of the children born annually per 1000 women aged 15 to 50 as one proceeded from the slums to the quarters of the rich. He gives this decrease as follows: In Paris, from 108 in the very poor quarters to 34 in the very rich; in Berlin, from 157 to 47; in Vienna, from 200 to 71; in London, from 147 to 63. It has been found that in London (1903) the *corrected birth-rate* (that of the whole of London being taken as 100) was 118.8 in the poorer quarters, about 95 in the middle class quarter and 77 in the quarters of the rich. Dean Inge, in a note to his essay on the birth-rate, says: "The births per 1000 married men under fifty-five in the different classes are: Upper and middle class, 119; intermediate, 132; skilled workmen, 153; intermediate (workmen), 158; unskilled workmen, 213."

In our own country there is abundant proof that the people with higher standards of living are being displaced and supplanted by those with lower standards. People of native stock in the cities and in the northern and western states are fast being supplanted by immigrants and their children. Graduates of women's colleges have scarcely enough children to replace themselves, to say nothing of replacing their husbands. Small cities in the eastern states having distinctly different population groups—*e g.*, Auburn, Maine, largely of native stock, and Lewiston, Maine, largely of French-Canadian stock—have large differences in their birth-rates, that of the latter being about 10 per 1000 higher than that of the former. The studies of the Immigration Commission showed that in several different localities the number of children born to mothers of foreign parentage averaged much higher than the number born to native-born mothers of native parentage and that the difference was greater in cities than in the country.

Recently the Census Bureau in its report on birth statistics for 1920 has set forth a number of interesting facts in the tables relating to the size of families. In North Carolina during 1920 14.9 per cent. of the native-born white women 20 to 49 years of age reported

births, in Ohio the percentage was only 8.4, in New York it was 7.6, in Kansas 9 9, in Washington 8.2, in Virginia 12.5. Thus it appears clear that in the south, where the standard of living is lower than in the north, children are more numerous. This is also shown by the number of children born to the wives of men engaged in various occupations who reported births during 1920. The wives of professional men had born about 2.2 children, the wives of miners had born about 4.3, of farmers 3 8, of bankers, brokers and money lenders 2 3, of managers, superintendents, etc., in manufacturing 2.5, of laborers in manufacturing 3 7 and of semi-skilled operatives in manufacturing 3.0. So far as one can judge of economic status from occupation there is no question but that the better this is, the smaller is the number of children born in the family.

The evidence that this process of the supplanting of people having higher standards by those of lower standards is going on all over the world is conclusive. A higher standard of living has no biological value. It tends to substitute voluntary control of population growth for the processes of natural selection. It seems quite probable, therefore, that if people having high standards of living expect to survive they must be prepared to control the processes of competition between themselves and people with lower standards, both by restricting the movements of peoples and by encouraging the spread of knowledge regarding the means of birth control to all classes of the population. They must also learn to use birth control as a method of limitation rather than of elimination as is so often the case at the present time.

The Causes of the Supplanting Process

Greater Economic Efficiency and its Consequences

The reasons for the supplanting of people with higher standards of living by those with lower standards when the two come into competition are not far to seek. The people with lower standards generally share in the benefits of a more efficient economic system developed by the people of higher standards so that they obtain a larger return for their work than they are accustomed to. They work with the capital accumulated by people with higher standards or they sell their produce in a market developed by a highly organized transportation system or they make use of the labor of women and children in productive processes in a degree not customary among people with higher standards. Though most of the increase in product obtained by more efficient work goes to the employing class, sufficient goes to the laborer to give him command over more goods than he had under the less efficient system. This surplus acts immediately to remove some of the economic causes of a high death-

rate. Thus a larger number of the children born to these people survive and their rate of natural increase mounts rapidly. Parents can feed, clothe and house more children than they could have done with the same expenditure of energy under a less efficient system and yet have more for themselves than ever before (more leisure, better clothes, better food, better house, more furniture, etc). Thus it happens that the rearing of the larger proportion of children that survive because of the easier struggle for existence is not felt as a hardship.

Improved Sanitation

When coming into competition with people having higher standards, people with lower standards also share the sanitary improvements of the latter The advantages of a good water supply, closed sanitary sewers, medical clinics, school medical examinations, etc., where they are present at all, are rapidly extended to the lowest economic classes If no higher motive prevails, self-protection serves to stimulate the extension of health agencies to all classes. The result is that the people with lower standards who always have a higher birth-rate increase more rapidly than those having higher standards This condition lasts for some time, often for generations, for the forces working for a reduction of the birth-rate are much more complicated than those working to reduce the death-rate and do not come into operation so quickly.

The death-rate depends directly upon the economic status of a group. So direct is the relation between the economic condition and the death-rate that if one were to arrange the countries of the world in order of their death-rates, one would find that, almost without exception, they were also arranged in order of the economic welfare of the masses of the people—the highest death-rate existing where poverty is most pronounced. This is just as true of the different economic classes within a country as it is of different countries. The only exception that needs to be made to this statement is that if the age and sex groupings in a country or class are peculiar the death-rate of the groups so affected will reflect this peculiarity, so that on the face of the figures the above statement may not appear true, while a corrected rate will show its truth beyond dispute.

THE CAUSES OF A LOWER BIRTH-RATE

An enumeration of the forces making for a reduction in the birth-rate will show that these forces are much more complicated than those making for a reduced death-rate and are much more closely associated with the whole cultural development of people than the latter. As a consequence the birth-rate does not respond

to a change in economic conditions in the immediate way in which the death-rate does. The forces making for a reduction in the birth-rate may be summed up under the following heads: ambition, desire for self-development, love of luxury and ease, desire to give one's children the best possible start in life and sterility due to vice and also probably to over-eating and sedentary life. These are the "preventive" checks. It will be seen that all but the last of these, *viz*, sterility, may be called "psychological." That is, they come into operation because of the desire of people to limit the size of their families. Whether people will have this desire and how strongly it will operate will depend upon many factors—the nature of one's ambition, the accustomed standard of living and the ease or difficulty of maintaining it, the education desired for one's children, the relative values one places upon material and spiritual achievement and many other factors which cannot be enumerated, but which may be summed up in the expression, *cultural atmosphere* Since the whole body of habits, traditions, customs and interests which go to make up the cultural atmosphere change much more slowly than the economic conditions, especially in the case of immigrants and of the nations which are coming within the sweep of modern industrial development, the birth-rate of these people changes more slowly than their death-rate. The result is a great and almost immediate increase in the rate of natural increase of people having low standards of living when they come into competition with people having high standards

The "psychological" causes of the reduction of the birth-rate just enumerated lead to its voluntary control by individuals through postponement of marriage, through remaining unmarried and through limitations of births after marriage. There will be no serious question in the minds of most people that the upper economic classes are those who will make most use of these means of keeping the birth-rate low. Let the reader who questions this position ask himself: What class of people (men or women) are most ambitious? What people need to provide longest for their children—especially for their education? What people feel the need of travel and leisure to develop themselves and make their contribution to the work of the world? What people find their earning power relatively low from 25 to 40 or 45, just when they should be raising a family? And, finally, what people become lovers of an ease and luxury incompatible with the raising of a fair-sized family?

What can be done about it?

It was said above that a high standard of living is not a biological virtue. If people who possess high standards of living are to perpetuate themselves and maintain good standards two things

would seem necessary: First, they must see to it that their standards of living are not so complicated and elaborate that they make no allowance for the raising of fair-sized families. A high standard of living does not need to be a luxurious standard and love of luxury, ease and desire for self-development must not be over-emphasized. This means that a great many middle class and wealthy people must simplify their mode of life and that the ideal of a satisfactory life which they set up must be made to include the rearing of a fair-sized family. The atmosphere in which they live and the general class standards they uphold must be revised so that they favor a fine type of family life. They must come to regard success in life as involving the raising of a family of three or four children so that they will feel that they have failed of complete success in so far as they do not do this Standards, ideas, customs and habits which interfere with this should be placed under the ban of class disapproval. I am fully aware of the obstacles to the erection of a fine type of family life into one of the effective ideals determining conduct, but unless this is done the people in the upper classes and those nations which have worked their way to the higher cultured levels will perish from the earth in a few generations *"Blessed are the meek; for they shall inherit the earth."*

There can be no doubt that the people in the upper classes of all nations belong to that half of the nation which has the better inherited capacities. That it is a calamity to a nation to have its better stock die out as rapidly as it is now doing in most of the nations of the western world will be generally admitted. But not only are the people of proved ability leaving few or no descendants, so that there is a constant dying out of their families, but the cultural achievements of these people are also retarded in their spread because of their lack of offspring.

There is a social inheritance just as there is a biological inheritance and the family is the most efficient agency for the transmission of the former as well as the only recognized agency for the transmission of the latter. It is not too much to say, therefore, that even if there be an inexhaustible supply of first-rate ability among the people of the poorer classes, yet the progress of a nation is greatly retarded by the failure of the upper classes to raise fair-sized families; for the very great advantage of being reared in a family where cultural attainments are considerable is thereby denied to almost all the members of each new generation. Thus each person who aims at cultural achievement has to start at or near the bottom of the ladder and naturally he can not go as far in his lifetime as he could if he had had the advantages of being reared in a home where cultural attainments of a high order were a natural

part of his social inheritance. Thus the failure of the upper classes to propagate themselves is both biologically and socially a calamity.

The second thing that must be done if people having high standards of living are to perpetuate themselves is to prevent a too sordid economic competition between themselves and people having lower standards. We already recognize this fact in numerous ways. We are now restricting immigration and are likely to still further restrict it in the near future. We have had child labor laws for some decades and are constantly strengthening them. Thus we prevent parents from depending upon the economic activities of children to add to the family income, and at the same time prevent competition between adults and children. We have compulsory education laws; we have minimum wage laws; we have laws fixing the conditions under which people may work; we have workmen's compensation and employers' liability laws; we have labor unions fixing the numbers of apprentices, the methods of their choice and the periods of training, also fixing the hours in a day's work and making many other regulations regarding the conditions of work. All these restrictions tend to make it possible for certain groups to maintain standards of living which they would not be able to maintain if competition were unrestricted between themselves and people having lower standards.

I would not hold that it is desirable to maintain all the standards of living we are now maintaining by restricting competition between groups. Too much restriction may lead to stagnation of effort on the part of any group or class; but I would hold that when a group (race, nation or class) has raised itself out of the slough of poverty it cannot be expected to sit calmly by and watch itself perish from the earth because other peoples are still in the slough. For, if competition is unrestricted, the people with lower standards are the ones who will survive. Just as the baser money drives the better money out of circulation because the former is relatively over-valued, so people with lower standards of living supplant those with higher, because their qualities have a greater economic and biological value, that is, are over-valued, in a system where mere volume of production is made the test of national greatness and acquiring the ownership of large quantities of the products is the chief test of the individual's success.

SOURCES OF WATER SUPPLY FOR DESERT ANIMALS

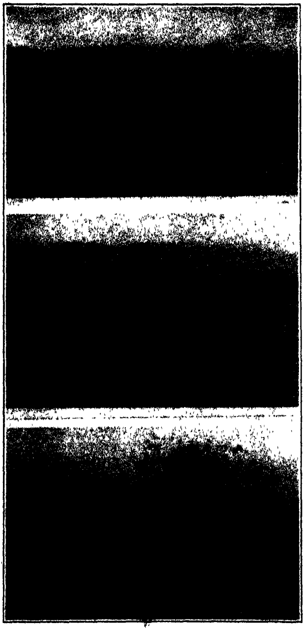
By VERNON BAILEY

CHIEF FIELD NATURALIST, BIOLOGICAL SURVEY, U. S. DEPARTMENT OF AGRICULTURE

THE well-known fact that our driest deserts are abundantly populated with animal life has caused much surprise and speculation. Insects, reptiles, birds and mammals are generally common and, in varying proportions, often far more numerous than in humid climates of flowing streams and dense vegetation.

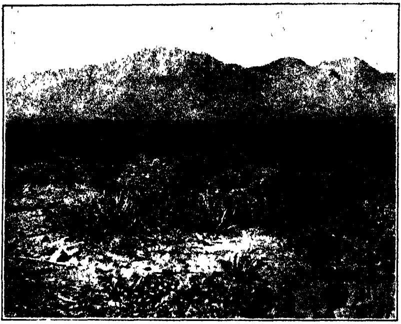
Of mammals the larger grazing forms are usually absent for the evident reason that there is comparatively little food of their liking, but the browsing ruminants—the deer, antelope and mountain sheep—are often found in local abundance. The smaller carnivores—coyotes, foxes, cats, skunks, badgers and weasels—are generally present, but the greatest abundance is usually found in the rodents, many groups of which are peculiar to desert areas. Some of these groups are highly specialized for desert life and comprise large numbers of species and subspecies found nowhere else and often found in great numbers in the very dry, hot and barren areas, where there is no open water, no possibility of obtaining subterranean water and where there is often no rain or snow or dew for months or years at a time. Even in the midst of long dry periods these desert animals are found in perfect health and good bodily condition, with abundance of internal fluids and secretions, often with the bladders well filled with water. The young are produced, and the mothers seem always to have a copious supply of milk for them as they grow up without a knowledge of what water looks like or that such a thing exists.

There has been much speculation as to how these animals obtain sufficient moisture for their needs, and many theories have been evolved. Prairie dogs and other burrowing species have been supposed to sink deep wells, but they often live where no water is available for many hundreds of feet down through solid rock formations. At first thought it would seem that they might get water from succulent food, but most of the desert vegetation contains little moisture and many of the animals live largely on dry seeds of desert plants, while some have been kept in confinement



THE SOUTHERN ARIZONA DESERTS

With an average rainfall of 7 to 10 inches a year these deserts bear scattered plants of cactus, mesquite, creosote bush, and many low shrubs of the *Compositae* called *rabbit-brush*, all of desert types and widely spaced.



THE DESERTS OF WEST TEXAS

Along the Rio Grande Valley are dry and hot slopes, by no means barren of vegetation or animal life Cactus, creosote bushes, catsclaw, yuccas and agaves are conspicuous, while grasses and small plants are scattered here and there.

for considerable time with no other food than seeds or grain. Juicy insects and insect eggs have been thought to supply the necessary moisture, but in the stomachs of many of the species examined insect remains are scarce or entirely wanting. The conversion of starch and other carbohydrates of the food into water has been demonstrated as a chemical possibility and perhaps given more prominence than the facts would warrant.

Theories have been numerous, but actual experiments and close observations few.

By far the most important paper on the subject is by Dr S. M. Babcock,[1] who shows how carbohydrates, fats and protein may be chemically converted into 50 to 100 per cent. of their weight of water by oxidation or molecular change within the cells of the body, thus supplying much of the water necessary for vital processes, and in some insects ample water for growth and reproduction when living on air-dried food containing only 10 per cent. of moisture He also shows that birds and reptiles as well as insects conserve moisture by eliminating the poisonous wastes of the vital processes as dry salts of uric acid, but that mammals which have the same power of converting these food elements into water must eliminate their waste in the form of liquid urea. He further informs us that this metabolic water would be sufficient for all vital purposes in mammals but for the necessity of elimination of poisonous waste in liquid form To what extent mammals can really live with water obtained only from relatively dry food he leaves us still in doubt.

It must be granted that animals long accustomed to desert conditions have become especially adapted in habits and structure to the conservation of moisture. They have dry firm skins which retard perspiration; their feces are dry and carry away only a minute trace of moisture; they are largely nocturnal and burrowing and not exposed to the drying air of the hot days; and above all they know where to find a permanent supply of choice foods. In studying them, however, each species must be taken separately, as the habits vary widely and in even the same species may differ materially in different localities and at different seasons. The following species will serve to illustrate the habits in several groups.

Rabbits

The antelope jack rabbit (*Lepus alleni*) is a typical desert species occupying western Sonora and southern Arizona, living on dry valley slopes and mesas where for long distances no water is avail-

[1] Babcock, S. M., "Metabolic Water, its Production and Rôle in Vital Phenomena." Research Bull. 22, U. of Wis. Agri. Exp. Sta., pp. 87–181, 1912.

able. Even where open water does occur they apparently do not go near it, even in periods of long drought. The greater part of their food is green grass and growing vegetation, but throughout their range many species of cactus are abundant, and at all seasons the rabbits habitually feed on cactus pulp to any extent they wish. The large prickly pear or pad cactus (*Opuntia engelmanni*) is generally eaten more than any other species, evidently because the most abundant and least spiny cactus where they range In Arizona most of these plants are more or less eaten by the rabbits, and some near the trails are almost entirely devoured. The stomachs of rabbits shot usually contain considerable quantities of the bright green, moist and mucilaginous pulp of the cactus pads. By weigh-

ENGELMANN CACTUS PADS
Showing how the jack rabbits eat between the spines on some and bite out the edges on others

ing a green pad of this cactus, drying out and again weighing, I found that it lost 78 per cent of its total weight by evaporation of water. The edible part would have a still higher water content.

The common "viznaga" or devil's head cactus (*Echinocactus wislizeni*) of the same region is also eaten when the rabbits can get at it, but usually the rigid straight and hooked spines protect it from external attack. When injured, broken or cut into, so that the rabbits can get a start on one, it is soon eaten out hollow and finally killed as its great store of moisture is lost. By splitting open one of these viznagas with an ax, quartering and leaving it exposed I found that the rabbits soon gathered and devoured all but the spiny shell. The crisp juicy flesh of this cactus showed by evaporation 94 per cent water and the whole plant about 90 per cent.

Over sections of dry, sandy valley slopes I found numerous little pits dug a few inches deep by the jack rabbits. The bottom of each of these showed the remains of a partly eaten tuber, averaging about the size of my finger. Digging them up, I found them of various lengths with dry hard caps or scabs over the top of each where they had been previously cut off and healed over, often several of these dry caps lying close by where the tuber had been eaten at different times. The plant proved to be a member of the Purslane family (*Talinum angustissimum*), and the rather solid tubers

ENGELMANN CACTUS

Large plants are found half eaten up by jack rabbits and occasionally the whole plant is consumed down to the woody base, from which new shoots start up when the next rain comes.

showed by desiccation a 70 per cent. water content. A small portion of these tubers was often found in the rabbit stomachs and the thousands of little pits where they had been dug showed them an important source of supply of both food and moisture.

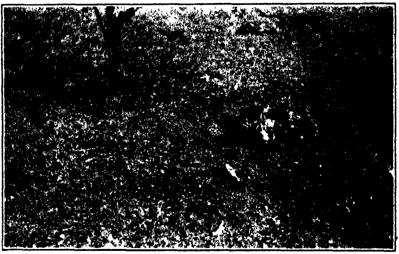
The rabbits are in part diurnal, but are active mainly at night or in the early morning and evening, when the air is cool and moist. Green grass and many plants with green foliage were regularly sought and the new leaves eaten off as fast as they appeared above ground while tender and juicy. The well-masticated contents of rabbit stomachs generally showed a mass of green vegetation with a moisture content of 78 to 82 per cent., or about the average moisture of their green food plants.

As the droppings of the rabbits are almost dry, and the urine is thick and milky and not very copious, there is evidently little loss of moisture from the bodies and a constant and ample accumulation

of it from the food. As other fresh growth dries up they still have many kinds of cactus and underground tubers and bulbs to depend upon for moist food. The same generalizations apply more or less to other species of rabbits which abound in desert regions.

KANGAROO RATS

Kangaroo rats and pocket mice fall into a group with very different habits from those of the rabbits, being mainly seed eaters, burrowers and night workers. They inhabit our driest deserts and have been credited with living indefinitely without water. In the wild state their principal food appears to be dry seeds of numerous plants, and the stomachs generally contain a starchy mass of clean white dough, with occasionally a bit of green vegetation or moist

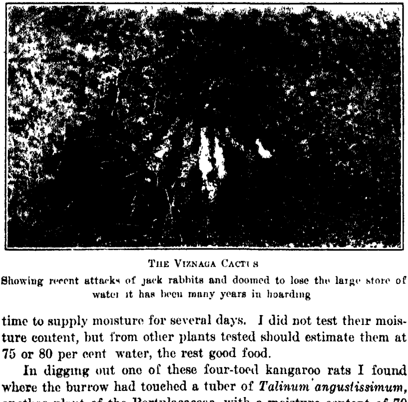


VIZNAGA CACTUS

The top was cut off this cactus, and two weeks later the antelope jack rabbits had left only the spiny shell and a circle of characteristic pellets around it. The cactus was not large but may have yielded 50 pounds of water.

plant tissue. There are accounts of their having been kept alive for long periods on dry seeds with no water, but in many cases I have found that after being kept for a week on dry food they are extremely thirsty and drink eagerly and repeatedly as if famished. In fact, some have died after two or three weeks without water or green or moist food. They are always eager for juicy cactus pulp, crisp lettuce leaves or green grass, although eating but little at a time. Their conservation of moisture, through dry pellets, slight deposits of urine, nocturnal and burrowing habits, evidently enables them to live with very little moisture. In many cases, however, I found where they were obtaining all the moisture they needed in the most arid sections of southern Arizona.

Dipodomys merriami, typical of its group, ranges in Lower Sonoran Zone from El Paso, Texas, west through the Gila and Colorado valleys of Arizona and eastern California in the hottest, driest part of the United States. In the dry valley south of Tucson, Arizona, during a dry winter following the unusually dry summer of 1920 they were common and in their usual plump condition. Many were caught alive for study and others dead for specimens. One caught and instantly killed in a snap trap had its pockets filled with the little juicy tubers of a small *Portulaca* that grows abundantly over the desert and is generally available an inch or two below the surface of the ground, even during a drought of several years Enough of these were carried in the cheek pockets at one



THE VIZNAGA CACTUS

Showing recent attacks of jack rabbits and doomed to lose the large store of water it has been many years in hoarding

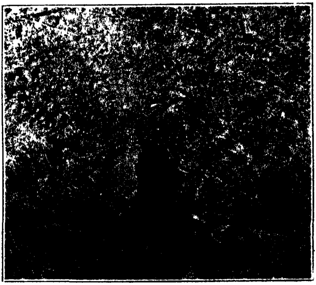
time to supply moisture for several days. I did not test their moisture content, but from other plants tested should estimate them at 75 or 80 per cent water, the rest good food.

In digging out one of these four-toed kangaroo rats I found where the burrow had touched a tuber of *Talinum angustissimum*, another plant of the Portulacaceae, with a moisture content of 70 per cent. This large tuber had been eaten into on one side and probably contained enough watery food to supply one kangaroo rat for a month. Thousands of little pits dug over the surface of the ground by small rodents show where roots and bulbs and tubers, all more or less juicy, have served as food and drink

In the sandy washes grow an abundance of small composite bushes (*Hymenoclea monogyra*), and their long roots bring up

moisture, if any is to be had Their white, juicy buds and sprouts starting below the surface of the ground are so much sought by the kangaroo rats that trails lead to the base of each bush, where much digging is done for this source of water and pleasant food. The sprouts are comparable to fresh, crisp head lettuce and I should estimate their water content at 90 per cent

In captivity these little animals drink water regularly if given only dry seeds and rolled oats and get very thirsty if they are not given water in any form for a few days They eagerly accept viznaga (cactus) pulp in place of water and eat considerable of it



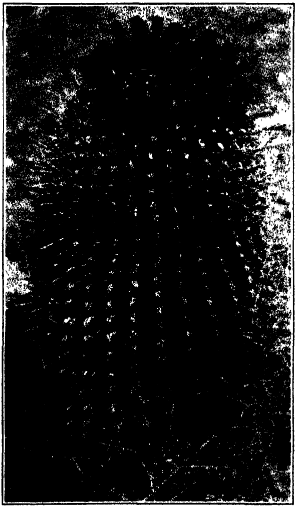
PIT DUG BY ANTELOPE JACK RABBIT

One of the characteristic pits where an antelope jack rabbit had dug down and eaten part of the juicy tuber of a *Talinum*, an abundant desert plant but so little noticed that it has no common name. Rabbit tracks were fresh in the sand

every night, often carrying pieces into their nests to nibble at during the day. They also will eat new grass, lettuce, celery, apple and a great variety of juicy foods One was kept in a cage for a couple of months without any water, but a grassy sod about six inches square in the cage was kept moist and as the grass grew the green tips were eaten off close down. The sod was over-grazed, but the kangaroo rat kept in good condition Such young grass contains about 80 per cent. water, but as the blades grow older the moisture content decreases to 70, 60, and even 50 per cent.

The large, banner-tailed kangaroo rats, *Dipodomys spectabilis*, are in some ways unique in habits, building mound-houses and

storing large quantities of food to last through the winter and through long periods of drought or scarcity. They occupy the driest areas of southern Arizona, New Mexico and western Texas,



A MEDIUM-SIZED VIZNAGA

This plant, four feet high and a foot and a half in diameter, would weigh over 300 pounds and was approximately 90 per cent. water. Its crown of 50 ripe, yellow, pear-shaped fruits was still intact on March 28, 1921, owing to the effective armor of spines.

where often no water is available for months at a time. Their stores are mainly seeds and dried vegetation, but at all seasons they can find moist vegetation on or under the surface of the ground.

In captivity for nearly three years these animals have required either some green or juicy vegetation or considerable water to drink, and after a few days are evidently suffering if deprived of both. If plenty of green or moist food is supplied they will not touch the water; if not, they will drink considerable each day. In

TUBERS OF TALINUM

Many tubers, partly or almost wholly eaten by the rabbits, were dug up, photographed, weighed and dried out to get their moisture content. Woody caps or scabs formed over the tops after they were partly eaten and prevented further evaporation of their moisture.

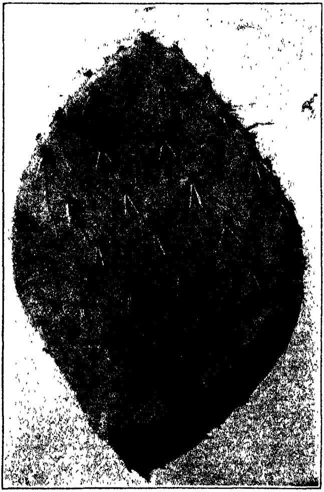
an eight days' record of food given a family of one old female and her three nearly grown young, after their food habits were well known, the following results were obtained.

GREEN AND DRY FOOD EATEN IN EIGHT DAYS

Clover	199 grams, water content 147 7 grams (74.3 per cent.)
Grass	12 grams, water content 7 5 grams (62.5 per cent)
Lettuce	35 grams, water content 31 5 grams (90 per cent.)
Total	246 grams of moist food, 7.7 grams each per day.
Rolled oats	69 grams
Corn meal	10 grams
Seeds	98 grams
Total	177 grams of dry food, 5 5 grams each per day.

Total food eaten per day by each 13 2 grams.
Water obtained by each from green food 5.8 grams
Solid food eaten by each per day 7.4 grams.

Weight of animals, 121, 104, 99 and 98 grams = 422 grams
Average weight of animals 105.5 grams.
Average daily food for each 7 4 grams, 7 per cent of weight of animal.
Average daily water for each 5.8 grams, 5 per cent of weight of animal.



ENGELMANN CACTUS

A single pad, or joint, 9 by 12 inches and half an inch thick, weighed 22 ounces, and when split open and thoroughly dried out in open air 17 ounces, losing by evaporation 78 per cent. of its weight of water. In addition to the water it is excellent food and but for the spines would have been exterminated long ago.

Their pellets were almost as dry as the dry food, but the deposits of urine were copious, probably unnecessarily so from the abundance of moist food eaten. All were in perfect health and bodily condition.

Pocket Mice

In western North Dakota in 1919 I kept some pocket mice (*Perognathus flavescens perniger* and *P. fasciatus*) in a cigar box in my grip while traveling from place to place and fed them on the various weed seeds which they liked best, mainly seeds of pigeon grass and Russian thistle. After about six weeks of such dry and simple diet I could see that they were not thriving, as they were getting very light in weight and their hair had a fuzzy, erect, unnatural look. Still, they refused to drink water and were greatly displeased or alarmed if by accident they got their noses or feet into a water dish. They would shake it off and roll and rub in dry sand until perfectly dry. One day it snowed and I sprinkled a little fine snow in their cage. They began to eat it eagerly and for a long time could not get enough. For several days I gave them snow every day, and soon they plumped up and looked as sleek and bright as ever. When the snow was gone I gave them a dish of absorbent cotton saturated with water and every day they were seen sucking at it for a few moments at a time. Later they learned to drink from a dish of open water, but in a peculiar way, dipping up a handful and turning the head to one side and licking or sucking it from the hand, repeating this five or six times, or when very thirsty as many as ten or twenty times. The usual method of drinking is apparently unknown to these little animals, but in their semi-humid range where dew falls they probably eat dewdrops in summer and snowflakes in winter.

The important fact is that on dry seeds they could go apparently six weeks without water and suffer no serious harm. Possibly, however, some green vegetation may have been offered them during that time and eaten without my knowledge, and I know that many of the seeds were not fully ripe. Now, after three years of captivity, these pocket mice occasionally get in poor condition, look rough and fuzzy, and I find they are very thirsty. When given plenty of fresh lettuce leaves, which run as high as 95 per cent. water, they keep in good condition without other water.

Gophers

Many species of pocket gophers occupy the desert region, but mainly in the more moist and fertile bottomlands or the mountain valleys where there is considerable rainfall and a richer growth of vegetation. A number of species, however, live by choice or necessity on very dry and barren valley slopes where it would be impossible to obtain water except at long intervals. They live mainly under ground in closed tunnels and feed on roots and bulbs en-

countered in extending their tunnels and on such green vegetation as they can find near their doorways when the burrows are opened for throwing out earth. As much of the desert food and moisture are stored under ground, the gopher's manner of living is most advantageous.

Several species of these little burrowers kept in captivity for a year or less time have lived largely on moist food, green vegetables, roots, tubers or succulent foliage. They seem never to drink water and carefully avoid touching it if placed in their cages.

Ground Squirrels

A little desert ground squirrel (*Citellus tereticaudus*) taken on April 18, 1911, near Continental, Arizona, had its stomach about half full of moist food, about 90 per cent. green vegetation, five per cent. pulp of tuberous or bulbous roots, and five per cent. small insects. The contents weighed 12.2 grams while fresh, 2.2 grams when dry, losing 9 grams or 81.2 per cent. of water by evaporation. This is about the moisture content of succulent vegetation, and considering the dry pellets of these squirrels evidently leaves abundance of moisture in the system. In captivity for over a year one of these little squirrels was healthy and apparently contented on a diet of seeds, grain, apple, lettuce and other green foods. Apparently he never touched the water that was occasionally put in his cage, and where he was caught there was no possibility of his getting water.

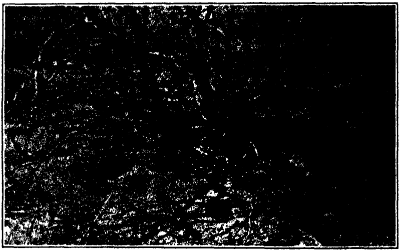
The little spotted ground squirrel (*Citellus spilosomo macrospilotus*) was also kept for about a year on the same kind of foods and with the same negative results in regard to drinking.

The antelope squirrels, sometimes called chipmunks because they have one stripe along each side, are typical of the deserts. In Arizona I found them living through a dry winter very largely on the seeds and pulp of cactus fruit, the big yellow pear-shaped capsules of viznaga. Their stomachs were found full of the little moist black seeds, chewed-up shells and all, and mixed with the juicy pulp of the capsule. Dried out in the open air the seeds lost 34 per cent., and the pulp 85 per cent. of water.

Grasshopper Mice

The grasshopper mice (*Onychomys*) are common in the driest areas, but their food is largely insects and other small animals, which derive their moisture from plants or other plant-fed life. While in the wild state these mice seem entirely independent of free water, in captivity they drink water or eat juicy vegetation

and suffer if long without an adequate supply of water or moist food. Juicy crickets, grasshoppers, scorpions, caterpillars and other larvæ form a large part of their food. These are taken on or under the surface of the ground and as only the fleshy or moist parts are eaten probably contain all the moisture required by the little nocturnal, burrowing mice. Dr. Babcock gives the water content of smooth caterpillars as 83 to 85 per cent. and beetles 50 to 62 per cent



THE HOME OF THE MERRIAM KANGAROO RAT

Is down deep in the ground, usually under a thorny bush where there is good protection and in summer a little shade. Usually the doorways are firmly packed with earth after the occupant retires for the day.

SHREWS

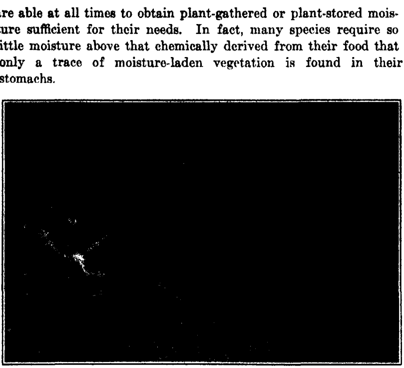
One genus of shrews (*Notiosorex*) is also an inhabitant of the desert region, but the individuals are so rare that little is known of their habits except that their food is mainly insects.

BATS

The bats, however, while living on the lighter and drier flying insects are exceedingly thirsty animals, rarely found beyond reach of open water, of which they drink each evening before beginning to feed Free of wing they have not acquired the adaptations of the more restricted rodents.

Much information is available on food and water habits of other species, but these few examples seem to indicate that desert rodents, with their acquired conservation and physiological production of moisture in addition to nocturnal and burrowing habits,

are able at all times to obtain plant-gathered or plant-stored moisture sufficient for their needs. In fact, many species require so little moisture above that chemically derived from their food that only a trace of moisture-laden vegetation is found in their stomachs.



THE LITTLE FOUR-TOED MERRIAM KANGAROO RAT

Lives only in the driest and hottest of our deserts, but he lives under ground in the daytime and does all his work at night when the air is cool and comparatively moist.

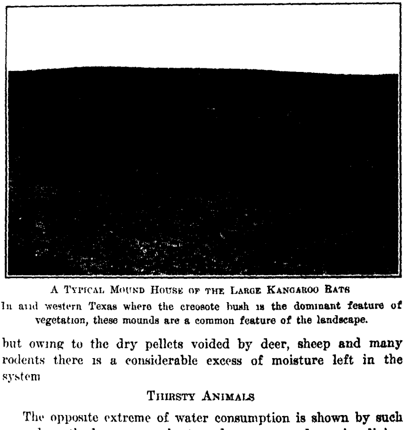
PLANTS EATEN BY DESERT MAMMALS AND THEIR AVERAGE PERCENTAGE OF WATER

Cactus—viznaga, inside part 94 per cent.
Cactus—viznaga, whole plant 90 per cent.
Cactus—viznaga, whole fruit 70 per cent. (without seeds 85, seeds 34).
Cactus—prickly pear, whole plant, 78 per cent.
Cactus—prickly pear, edible part 84 per cent. (estimated).
Hymenoclea monogyra, underground sprouts 90 per cent. (estimated).
Wild morning glory (*Evolvulus*), young leaves 70 per cent. (approximately).
Grass, young green blades, 80 per cent. (older blades 50 to 70).
Pigweed leaves (*Chenopodium*), 75 per cent.
Talinum tubers, 70 per cent
Portulaca tubers, 75 per cent. (estimated).

RUMINANTS

The ruminants are in another class of feeders for which we lack important data. Still, we know that mountain sheep and mule deer live permanently where there is no known source of water supply,

that antelope remain in open desert valleys at long distances from open water without coming regularly if at all to watering places, that cattle and horses will often remain out on the range for three or four days at a time without water if there is fresh new grass or other juicy vegetation, although they require water daily when on dry feed. Domestic sheep will usually go for several days without water if any green vegetation is available, and on fresh green grass or weeds in spring will sometimes remain for twenty or thirty days without drinking and suffer no harm In green food the carbohydrates are surely not sufficient to furnish much water,



A Typical Mound House of the Large Kangaroo Rats
In arid western Texas where the creosote bush is the dominant feature of vegetation, these mounds are a common feature of the landscape.

but owing to the dry pellets voided by deer, sheep and many rodents there is a considerable excess of moisture left in the system

Thirsty Animals

The opposite extreme of water consumption is shown by such animals as the beavers, muskrats and eastern meadow mice, living usually in or near the water and as observed in captivity, drinking heartily several times a day, although their food is largely of moist or juicy vegetation

The eastern gray squirrels require water once or twice a day and drink a considerable amount at a time. In fact, they will not long remain where water is not available. These extremes of habit in regard to water consumed are apparently due to physiological

adjustment of the system, but to what extent this adjustment is controllable or capable of variation within a species is not well understood. A muskrat is not more vigorous, well developed or healthy than a kangaroo rat, but either would soon die in the environment of the other

Water Required By Man

In June, 1889, the section foreman at Tacna, Arizona, a station on the S. P Railroad between Maricopa and Yuma, told me that four gallons of water to a man was the least amount on which he could keep his crew at work for 10 hours a day along the railroad

The Banner-tailed Kangaroo Rat

This is the largest of the four-toed group, conspicuous by its large mounds in the desert areas of southern Arizona and New Mexico and western Texas.

in hot weather, but at the same time I found that with a gallon canteen of water I could tramp over the valley for about six hours in a temperature of 105 to 110 in the shade, and no shade where I was. These tests, however, are under strenuous exertions which produce the copious perspiration necessary to cool the body by rapid evaporation. Men and horses perspire freely under muscular exertion, oxen and dogs but little, and many animals apparently not at all.

In the Death Valley country in the scorching heat of June, 1891, a gallon canteen of warm water would keep me comfortable all day in the saddle, while others less accustomed to the desert could barely survive on twice that amount of water. I also found

by some severe tests that thirst was greatly lessened by the moist air of night and that comparatively little water was needed while sleeping on the ground during the hours of darkness. We know the native Indians of the deserts school themselves to go a long time without water and when necessary to get a supply from the fruit and pulp of cactus and other plants which store it.

As we all know, the character of our food has a marked effect on our thirst and the amount of water we require. Also, if we do not drink all the water we want, that for considerable time no bad effects are noticed. Violent exercise and perspiration soon develop thirst and we suffer if the lost moisture is not returned to the system and the waste products removed

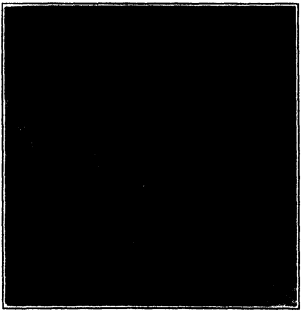
THE DESERT SPECIES OF POCKET GOPHERS

Live almost entirely underground and feed on roots, bulbs, tubers and such green vegetation as they find near the doorways, which are occasionally opened for the exit of surplus earth from their burrows. They apparently never drink water.

In a Department of Agriculture bulletin I find the average percentage of water given for various foods as follows:

Fresh lettuce,	94.7 per cent.	
Fresh spinach,	92.3 " "	
Fresh cabbage,	91.5 " "	
Whole milk,	87.3 " "	
Fresh apples,	84.0 " "	
White potatoes,	78.3 " "	
Beef steak,	63.1 " "	
White bread,	39.0 " "	(my own test)
Corn meal,	12.5 " "	
Whole rice,	11.0 " "	
Wheat flour,	10.8 " "	

In a careful two days' test of water taken into and pressed out of my own system I found that while only sufficient water to prevent thirst was taken, 26 ounces with an elimination of 38½ ounces one day and 30 ounces with an elimination of 42½ ounces the next, each day showed 12½ ounces of water to have come from my food. All liquids, soup, milk and fruit juice were included in the amount drunk. Otherwise the food was of the usual combination of meats, vegetables, cereals, breads and fruits. By increasing the vegetables, fruits and water-producing foods it seems probable that I might live comfortably for a considerable time, possibly



THE ANTELOPE SQUIRREL

Is active the year around in the deserts, feeding on green vegetation, green seeds and fruit, and in winter to a great extent on the seeds and fruit of viznaga and other kinds of cactus.

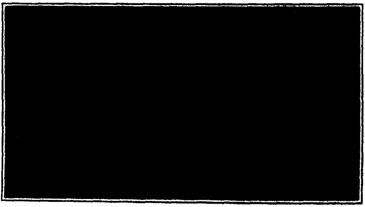
indefinitely, without drinking any liquids, providing, of course, that I was not taking violent exercise or exposed to dry, hot weather. If moving about only at night, sleeping all day in an underground burrow and with a few other slight advantages of adaptation to desert conditions, I might get enough moisture from my food for a healthy existence and become a true desert mammal.

CONCLUSIONS

These scattered observations and tests suggest the possible value of further investigations, requiring more time and better laboratory facilities. The bodily condition, gain and loss of weight,

THE LITTLE ROUND-TAILED DESERT GROUND SQUIRREL

Has no use for water in a free state but selects the tender, juicy young plants for food, and when the weather becomes very hot and dry in midsummer goes deep into his burrow and sleeps until the next February or March.



POCKET MICE

These little pocket mice belong to a desert group of rodents but have a wider range than the kangaroo rats and some of the species reach into the edges of more humid areas. Their bulging cheeks are partly filled with rolled oats and weed seeds to be eaten at leisure.

effect on growth, breeding, hibernation, aestivation and general welfare of not only desert but humid area species due to food and water conditions would be well worth careful study. The relative water productivity of different foods and combinations of foods should be determined for species in different groups of mammals under both normal and extreme conditions of climate. Some of the facts thus obtained might have an important bearing on the control of noxious species, on better development of ranges for game and domestic animals and even give to man a wider range of adaptation to extremes of climate.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

HAS SCIENCE REACHED ITS LIMIT?

"What is there left for me to discover?" is the common thought of the student as he looks about the library with shelves packed with books or the museum with cases filled with neatly labeled specimens. He realizes that when he enters upon research he is competing not only with his contemporaries, but with all his predecessors. No tariff can protect him from the pauper labor of antiquity.

"What are you scientists going to do when you find out everything about everything?" is a common remark of visitors to a laboratory. The scientist will doubtless reply that life is not long enough to find out everything about anything, but even he is apt to harbor the delusion that all the really big things have now been discovered and that future investigators will find pretty poor picking. Some scientists have been so rash as to put this opinion into print, much to the amusement of later generations. For instance, the great French mineralogist, Haüy, wrote at the beginning of the nineteenth century:

"Electricity enriched by the labor of so many distinguished physicists seems to have reached a time when a science has no more important steps before it and only leaves to those who cultivate it the hope of confirming the discoveries of their predecessors and of casting a brighter light on the truths revealed."

But we count this the beginning of our knowledge of electricity rather than its end, for over in London at this very time young Michael Faraday in his basement room at the Royal Institution was working out the relationship between electricity and magnetism which has led to the dynamo and the radio.

One might think that such a blunder as this would have made later scientists cautious about thinking that nothing much remained to discover, but no, for we find in 1894 the catalogue of one of the largest universities in the United States publishing at the head of its list of courses in physics the following discouraging statement:

"While it is never safe to affirm that the future of physical science has no marvels in store. . . . it seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice. . . . An eminent scientist has remarked that the future truths of physical science are to be looked for in the sixth place of decimals."

But the very next year Röntgen discovered the X-rays that led to radium and the electron.

When Newton laid down the law of gravitation the solar system was reduced to a simple mechanism and the movements of the planets could be accurately predicted. What was there left for the astronomer to do?

Bigger telescopes would doubtless reveal more satellites and show finer markings on the moon, but how could we ever hope to learn anything about the composition of the heavenly bodies? Yet now we can know how the electrons behave inside the atoms of stars whose light requires thousands of years to reach us, and Einstein has pointed out that even Newton's law requires modification.

Some branches of science may well have reached a terminal I suppose it is safe to say that about all the large animals on the earth have been discovered and described. It is true that the okapi, which is almost as conspicuous as a giraffe, managed to keep himself concealed in the African jungle until 1900, but not many such can have escaped the eye of the zoologist. But he can make no end of queer looking animals when zoology becomes a constructive instead of a descriptive science.

The scientific discoveries of the twentieth century have not only been more numerous than in any previous century, but they have been greater. Our investigators are not engaged in verifying the sixth decimal, but are projecting far-reaching and fundamental theories.

When you throw wood on a campfire in the night you expand the lighted area, but you also extend the circle of the surrounding darkness. So it is with science. With each increase in enlightenment a larger circle of surrounding ignorance is disclosed.

RELIGION AND SCIENCE

Timid souls who have become alarmed at the idea that religion and science are inevitable antagonists should be assured by the "Joint Statement upon the Relations of Religion and Science," signed by a number of the foremost scientists, religious leaders and men of affairs of the United States. These thirty-five distinguished thinkers in various fields found it easy to agree upon a simple statement of their opinion of the relation of religion and science and their belief that both have a place in modern life. No one can question either the ability or sincerity of such men as these, and, since their adhesion to the declaration is purely voluntary, it is evident that they find no essential incompatibility between a personal religious faith and a scientific view of the universe.

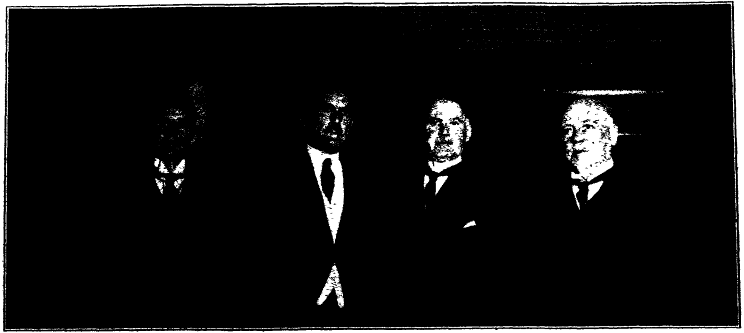
The list of signers could be extended indefinitely; in fact, the statement probably represents in general the position of most of the educated and moderate minded men of our time and country.

It is a curious feature of the present situation that the laity are more alarmed over the advances of science than the clergy. That is, those who know the most about theology and who have most at stake in the church are most willing to welcome historical criticism and scientific research. The real conflict is not between science and religion as such, but rather between dogmatic and intolerant religionists and scientists, on the one side, and liberal and tolerant religionists and scientists, on the other side. It is more a difference of temperament than of opinion. The effort to fetter freedom of investigation or to force thought into fixed formulas is equally fatal in science and religion.

Overmuch fear of heresy indicates lack of faith. Scientific men have such absolute confidence in the validity of the scientific method that they permit their most fundamental principles to be challenged even in their own societies. Chemists listen without a shudder to destructive attacks

Bust of Pasteur

Presented by the Pasteur Institute at Paris to the American Museum of Natural History, New York



Dr. William S. Thayer, of the Johns Hopkins University; Ambassador Myron T Herrick, the Honorable S P Spencer and Dr. William H Welch, of the Johns Hopkins University

The photograph was taken at the Sorbonne during the celebration in honor of the centenary of Pasteur's birth.

upon the immutability of the elements and the indivisibility of the atom. The Royal Society of London even applauds a speaker who sets an upstart foreigner like Einstein above Newton, one of its oldest and most venerated members.

The papers have reported a half dozen cases of professors who have been dismissed from educational institutions under ecclesiastical control for teaching evolution but there has been no retaliation from those whom some call the "enemies of religion" I never heard of the National Academy of Sciences expelling a member because he was suspected of being a Presbyterian or of the American Association for the Advancement of Science blackballing a man because he had been baptized. Girard College is the only institution that excludes clergymen by charter, and I understand that the doorkeeper there is not very vigilant in searching every visitor to see if he has a dogma concealed about his person. If we begin to rewrite our text-books in science to suit a single sect, or section of a sect, we may soon have Methodist and Baptist zoologies, Protestant and Catholic chemistries, Jewish and Christian theories of gravitation, as we now have northern and southern histories, and proletarian and capitalistic economics.

Science and religion, properly understood, need never conflict, but should always cooperate in the advancement of the human race, for each supplies what the other lacks. Science provides the means by which human toil and suffering may be alleviated and shows how human life may be lengthened and enhanced. Religion gives inspiration to the individual, an aspiration to a high ideal. Science gives eyes to religion. Religion gives a heart to science. Knowledge is power. But power is impotent unless set in action, and dangerous if set in action by the wrong motive. Religion, unless enlightened by science, wastes its energies in vague longings or in fruitless and sometimes harmful efforts to remedy bodily or social ills.

Science may discover what conduct is most conducive to human welfare in the future. But science as such can not go beyond this. It can point out the best way, but it can not inspire the individual voluntarily to follow it against his personal interest. Mere knowledge can not of itself supply the motive for self-sacrifice for others or for the future. It can not make a mother risk her life for her child or a man risk his for his country. The altruistic impulse is a religious instinct, whether it is recognized as such or not. Science can supply the motive power. Religion must supply the motive.

THE FIGHT AGAINST THE POTATO

What would we do without the potato? None is so poor that he can not afford to eat it. None is so rich that he can afford to disdain it. If all the potato plants of Europe should suddenly perish and prove irreplaceable a large part of the population would have to starve or emigrate.

Yet the people fought the potato as though it were the plague when it was first introduced into Europe. They were used to the plague and regarded it as proper punishment for their sins, but the potato, coming from the wild west of America, was new and therefore to be feared.

Sir Francis Drake is supposed to have brought the potato to England in 1586, having perhaps taken the tubers, in the course of one of his privateering cruises, from some Spanish vessel, together with other less valu-

Wide World Photos

CHARLES C. CONCANNON AND FREDERICK E. BREITHUT

Mr Concannon is the newly appointed chief of the Chemical Division of the Department of Commerce Dr. Frederick E Breithut, of New York City, will investigate the chemical and dye industry of Germany for the Department. Dr Breithut will head a commission with headquarters in Berlin.

able booty, such as gold and gems. Anyhow, he is credited with it by the Germans who erected a monument in his honor at Offenburg in 1854 and struck off a medal to the British admiral as the savior of Germany in 1916 when a big potato crop enabled them to hold out another year.

But such honors always come by slow freight. It took people a hundred years or more to learn that potatoes were good for them to eat. They fed them to their pigs and cattle which, not having the prejudices of rational men, took to them readily.

The Germans also fed their prisoners of war on potatoes and it happened that one of them was a French chemist, Parmentier, who, having been captured in 1758, was held a prisoner in Hanover for five years and had to live largely on potatoes. One would have thought he would have acquired a distaste for them but on the contrary when he was released he urged his countrymen to cultivate the potato as a vegetable, "that in Times of Necessity can be substituted for Ordinary Food." But the French, even though starving, would not eat potatoes until finally Parmentier persuaded the king and queen to taste some and wear a bouquet of the blossoms. The people, seeing that the king and queen were not poisoned, consented to sample them for themselves.

In 1728 an attempt was made to introduce potatoes into Scotland, but they were denounced from the pulpit on two contradictory counts; that they were not mentioned in the Bible and so not fit food for Christians, and that they were the forbidden fruit, the cause of Adam's fall. They were accused of causing leprosy and fever.

In England the effort of the Royal Society to promote the cultivation of the potato was suspected to be a conspiracy of capitalists to oppress the poor. The labor leader, William Corbett, said, "It has become of late the fashion to extol the virtues of potatoes as it has been to admire the writings of Milton and Shakespeare," and he declared the workingmen ought not to be induced to live on such cattle food.

When the British army was sent to fight in Flanders—not in 1914 but a hundred years before—they acquired two shocking habits. They learned to swear terribly and they learned to eat potatoes. The monks of Bruges had introduced their cultivation by compelling their tenants to pay part of their dues in potatoes The farmers, seeing that the monks throve on them, began to save some of the crop for their own use.

In Germany our own Benjamin Thompson, having become Count Rumford in Bavaria, undertook to clean the beggars out of Munich. When he had rounded them up he had to feed them and being a student of dietetics he decided that potato soup was the cheapest and most nutritious food he could find. But he had to smuggle the potatoes into the kitchen secretly, otherwise he would have had a hunger strike in the poorhouse.

And so, thanks to the initiative of scientists, kings and monks, and to the involuntary assistance of pigs, prisoners and paupers, the world got the inestimable benefit of potatoes. I wonder what we are fighting to-day as wrong-headedly and vainly as potatoes were fought by our forefathers.

SHARK-TOWED SUBMARINES

It is funny that anybody should be surprised at a parliamentary allusion to Great Britain's determination to remain mistress of the seas when she has made that plain by legislation, poetry and action for the last four hundred years. It is only a few years since as her associate in the late war we joined in the singing of

Rule Britannia! rule the waves!
All thine shall be the subject main,
And every shore it circles thine.

But it is not so commonly known that one of the proposed methods by which Great Britain was to hold her supremacy of the seas was the use of submarines towed by sharks. The inventor of this ingenious scheme was Dr. Erasmus Darwin, grandfather of Charles, who derived more than one hint for his theory of evolution from Erasmus Darwin's volume of versified science, "The Botanic Garden"

The most famous passage in this curious work is that in which Erasmus Darwin anticipates the automobile, the steam tug and the airplane:

Soon shall thy arm, unconquered Steam! afar
  Drag the slow barge, or drive the rapid car;
Or on wide-waving wings expanded bear
  The flying-chariot through the fields of air.
Fair crews triumphant, leaning from above,
  Shall wave their fluttering 'kerchiefs as they move;
Or warrior-bands alarm the gaping crowd,
  And armies shrink beneath the shadowy cloud.

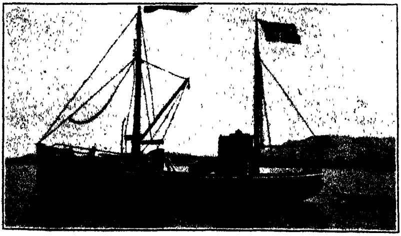
This is a good guess for 1789, although it is not steam but gasoline that we are using for automobiles and airplanes. But Grandfather Darwin could not anticipate the internal combustion engine, and he knew that steam would not work under water so when he undertook to describe a submarine he could not see how the boat could be propelled unless fish could be harnessed to it So he wrote:

Led by the Sage, lo! Britain's sons shall guide
  Huge *Sea Balloons* beneath the tossing tide;
The diving castles, roof'd with spheric glass,
  Ribbed with strong oak and barr'd with bolts of brass,
Buoy'd with pure air shall endless tracts pursue,
  And Priestley's hand the vital flood renew.
Then shall Britannia rule the wealthy realms,
  Which Ocean's wide insatiate wave o'er whelms:
Confine in netted bowers his scaly flocks,
  Part his blue plains, and people all his rocks,
Deep, in warm waves beneath the Line that roll,
  Beneath the shadowy ice-isles of the Pole,
Onward, through bright meandering vales, afar,
  Obedient sharks shall trail her sceptered car,
With harness'd necks the pearly flood disturb
  Stretch the silk reign, and champ the silver curb.

Absurd as this is as science and poor as it is as poetry, yet it has many points of interest. The author solved the question of submarine ventilation by the means now employed, that is, the renovation of the air by oxygen gas, which had been discovered only fifteen years before by his friend, Joseph Priestley, a preacher-chemist who was driven out of England and came to America because of his political and religious nonconformity.

But Erasmus Darwin made a bad guess in his surmise as to the motive power of the future submarine. Man has never been able to train to harness any animals of the sea. His control stops with the shore. And now he is getting ready to dismiss the ox and horse from their long servi-

MARINE BIOLOGICAL STATION OF THE BERGEN MUSEUM



"HERMAN FRIELE"
Collecting yacht of the Marine Biological Station of the Bergen Museum

tude and rely instead upon the inanimate energy of fuel and falls to run his slow barges and rapid cars as well as his flying-chariots and sea-balloons

THE NEW WORLD

The world we live in is a new world. Nobody ever lived in such a world before. It is a bigger world because there are more people in it. It is a smaller world because one can get around it quicker. It is a more complex world because of the many new forces that have entered into it. It is a simpler world to understand for it has been more thoroughly studied and classified. It is for the first time a known world, at least a knowable world. Practically all parts of it have now been explored. Most parts of it have been accurately mapped. Since Amundsen has visited the south pole and Peary has visited the north pole, no place on the globe's surface can be regarded as inaccessible.

We can now for the first time take stock of our resources and calculate our potentialities. We know just how much land we have at our disposal. We know that we shall never have any more land. We know pretty well what this land will grow and what it will not grow. We know how much food and what kinds each individual needs. We can then figure out how many people the earth can support at any given standard of life.

We can not see underground, but from looking at the edges of the strata where it is tipped up and from boring into it a mile or more in various places, we can tell about how much coal and oil, iron and copper, potash and phosphate, we have to go on, and we know that we can never get any more when this runs out.

In this new world of ours there is no more free land. The open range has gone forever. It is all staked out in private claims. Some flag floats over every bit of dry land. The last of the maverick territory, Spitsbergen, was caught and branded during the late war. This means that if any nation is to get more land it must get from some other nation.

There are many more nations than there were in the nineteenth century. Some twenty or more infant independencies are struggling for existence. If we call the cradle roll of the new-born nationalities we find them scattered from the Balkans to the Baltic, from Ireland to Azerbaijan, from Palestine to Vladivostok, all new and untried factors in the world's affairs.

War is new. It is fought with weapons hitherto unknown. Commerce is new. Strange commodities are carried by novel channels of trade. Finance is new. The old standard is lost and no one knows which nations are bankrupt and which solvent. Science is new. It is outgrowing its clothes, its old formulas and theories. Consequently it is more difficult than ever to predict the future or to apply the lessons of the past.

The historian, Seeley, once remarked: "When I hear a man say, 'History teaches us,' I say to myself that man is going to tell a lie and he always does" History can not help us much because it is the history of another and very different world from ours. So many unknown quantities have been introduced into our present problem that it can not be solved by the old rules.

THE SCIENTIFIC MONTHLY

AUGUST, 1923

SPENCER FULLERTON BAIRD AND THE UNITED STATES FISH COMMISSION[1]

By Dr. DAVID STARR JORDAN

STANFORD UNIVERSITY

I AM to speak to you to-night of one of the noblest of Americans, a commanding figure in New World science. More particularly, I wish to refer to certain episodes in Baird's life from which a moral may be drawn, and to stress somewhat fully a far-reaching project of his later life, the creation of the United States Fish Commission.

What I have to say must be largely a record of my own experience, for I can add little that is new regarding the character and work of Spencer Fullerton Baird. His life was all in the open, spent in the service of humanity. His letters have been lovingly edited by Dr. Dall. His books, papers and scientific notes, 1063 titles in all, I believe, have been duly catalogued. His methods and results have been reviewed by every student of birds, and have formed the solid foundation of the work of the Baird School of Ornithology, through whom we know the birds of North America better than any other faunal group anywhere else in the world.

I shall speak of the master as seen from my own viewpoint as one of the many struggling naturalists to whom Baird gave efficient and welcome help, even as Audubon, Agassiz and Dana had rendered aid to him And, in passing, it is to me a matter of great personal interest and gratitude to recall here the names of the three men who contributed most, each in his way, to my own development. These are President White, Professor Agassiz and Professor Baird. I may also say that in 1849 Agassiz and Baird planned a beautifully illustrated joint paper on the fishes of North America. Six fine plates in stone by August Sonrel were prepared and printed, but as neither of the two authors had time to

[1] Address at the Baird Centenary, at the Smithsonian Institution, February 3, 1923.

complete the work, it was laid aside and left to me, forty years later, to furnish a text for the illustrations.

Glancing over Baird's early history, we find many things characteristically American. He was born of good stock, most of his ancestors deriving from the fine, strong, persistent, obstinate group of dissenters who left the dissolute England of the seventeenth century to build homes in the free air and harsh surroundings of a New World. All of them alike, Puritan, Presbyterian or Quaker, were men and women clear-eyed, conscientious and unafraid, who lived the religion they professed. It is true that they lacked some of the virtues desired in these softer times. Too often, for example, they reduced religion to terms of logic, and conscience to intolerance. Reasoning from their experience in the England of the Restoration, they usually associated art with vice and dissipation, as many artistic souls do even to this day. But their stern code of life left no place for the weakling or the slave. In spite of the criticism directed in these lax and war-worn days against the Puritans and their kind, it remains a fact that they created our republic; no other type could ever or would ever have done it. Far and wide their descendants have ramified through the land, while their combined influence forms our best defense against aggression, external or internal, against red revolution and black reaction. In the rising tide of illiteracy, so dreaded by timid souls, who ever heard of an illiterate son of the Puritans or of the sturdily-mingled seventeenth-century group of English and Scotch yeomen, among whom were the forebears of Baird?

Said Starr King of these people:

> When they found that all which civilization had done for the old world did not nourish, but threatened to crush their manliness, they came to the wilderness to show, on a background of ice, granite and famine, that humble devotion to duty, reverence for the right, and vigorous will make men masters of the world.

Born in Reading, Pennsylvania, a hundred years ago this very day, Baird grew up a big, handsome youth, a keen student, eager to know, eager to help and eager to put knowledge in order, and with an intense devotion to natural history. He was especially fond of the study of birds and mammals, though he later developed an almost equal interest in reptiles and fishes. We may also note that he began, not with biological theories or the intricacies of life-mechanism, but with exact observation of whatever he found around him. His experience illustrates, I think, the normal way by which a biologist should be formed: the study of organisms as present entities alive and active, or, if dead, illustrating through their structure their relations to other forms and to their environ-

ment. Agassiz used to say: "If you study Nature in books, when you go out of doors you can not find her." Books have their place of course—a great and vital place if anything original is to be accomplished, or any large work to be done. To make a permanent contribution, one must find out at last all that others have seen or thought But books can not lead, contact with nature must come first The same holds true with dissecting rooms.

For the last thirty years, and in the interest of lines of study supposedly more fertile—morphology, embryology, animal reactions, Mendelism and genetics succeeding each other in turn—the tendency has been away from the old-fashioned study of nature Certain important pieces of research set the fashion for the others. Agassiz used to speak of those university students whose motto was "*Ich gehe mit den Anderen*" ("I go with the others")—a line of conduct repugnant to great minds We find, however, in science as well as in art, a tendency to go with the others, or, as Dr Coulter once put it in speaking of his contemporary botanists. "They all rush to dabble in the same pool"

In this vein, Professor James G Needham,[2] of Cornell, sounds a note of remonstrance

> We are all out of balance . . . Why not let the facts speak for themselves? Our laboratories are full of fashions They go from one extreme to another. In my high school days we learned systems of classification, in my college days we did nothing but dissecting, later came morphology and embryology, then experimental zoology, then genetics, and the devotees of each new subject have looked back upon the old with something like that disdain with which a debutante regards a last year's gown.

Nevertheless, there should be no question of the riches to be found in any pool of science. Every piece of honest research has its use, though not to the discredit of any other, and the refinement of taxonomy holds its place with the rest Accurate knowledge of animal or plant species is the foundation of the great science of zoogeography, as well as of its cognate branch, ecology. It marks especially the route over which the great naturalists of the past have been led to their specialties. It is, moreover, the normal beginning for those men who are to follow.

In his biography of Baird, Dall lays special stress on this phase of the work. "The method of instruction, by actual field excursions, which Baird employed in his classes of zoology and botany was new in America, and an original innovation with him. It was not unknown in Europe, and Agassiz's employment of it a year or two later at Cambridge gave a vogue to it in America which has

[2] *Science*, XLIX, 1919, p. 457.

been permanent. . . . Many references to the long tramps with his pupils are found in his Journal."

Dr. William Morton Wheeler,[3] in a recent very clever paper on "The dry rot of our academic biology," expresses the same idea:

> Dear, old, mellow, disinfected professors of the type of Louis Agassiz, Asa Gray, Shaler, Hyatt and Ryder enter at once into sympathetic rapport with the humblest amateur, but the young or those of middle age are almost invariably more or less priggish, condescending or worse. . . .
>
> And especially in the college we are unfaithful to our trust if we allow biology to become a colorless, aridly scientific discipline, devoid of living contact with the humanities.

I thus quote with no intention to criticize those highly endowed specialists who, in their various fields, with marvelous technique have opened up new vistas of the mechanism of life nor of those who deal with technical fragments or quantitative methods. I wish only to insist that the budding biologist can not begin with such work. I believe that the intensive study of living things around us, carried on accurately, not in sentimental fashion, is a means of grace to every scholar and a first step in preparation for biological research. It is well also to remember that biologists deal with the whole realm of life, which can not be seen in perspective from any single corner.

In an address ten years ago on "The making of a Darwin," I maintained that three things were necessary to this end: First, the right kind of germ-plasm, the hereditary stuff which determines high possibilities; second, contact with nature at first hand; and third, the presence of a sympathetic guide. In Darwin's case the material was of the best the centuries offer; in due time, also, the young naturalist wandered among the hills and fens of Cambridgeshire, collecting beetles and observing everything; and, finally, as he said, he "walked with Henslow," the spirit of the great botanist kindling his own. In like fashion, young Baird had it in him to be a great naturalist, he made the hills and streams of Pennsylvania his laboratory, and he "walked" with Audubon and Agassiz.

Baird's life may be divided into three parts, though each period shades off into the next—first, that of student and teacher, second, that of investigator, third, that of administrator. In early years his struggles to develop himself as a naturalist culminated in a scantily paid professorship at Dickinson College. During the second period he came to the Smithsonian as the chosen helper of venerable Joseph Henry, the original secretary and virtual creator of the institution. Now began his revision and expansion of the

[3] *Science*, LVII, 1923, p. 61.

knowledge of North American birds from his studies of the rich material brought in by surveys, and the inauguration, wholly informal, of the "Baird School" in zoology. Later, as executive, he managed and developed several scientific bureaus and sent out frequent exploring parties, at the same time extending a helping hand to struggling naturalists and in various ways making research possible

The first period is clearly revealed in the letters selected by Dall for his biography. The lad's enthusiasm over discoveries, his bent for intensive investigation as shown in his early monograph of the Flycatchers—the scientific spirit appearing in his interest in these dull-colored birds which appealed to him as strongly as the most comely of warblers—his reaching out for help, and a similar willingness to extend aid to others, all appear in that early record.

Baird's connection with the Smithsonian Institution dates back to 1850 To bring him there as assistant secretary had long been Professor Henry's plan. But lack of funds and uncertainty as to the future postponed the matter until the young naturalist reached the age of twenty-seven In his letter of appointment, he was asked to "take charge of making collections for the Smithsonian Museum and to request of officers of the Army and Navy . . . and of other persons such assistance as he might think necessary for the accomplishment of the intended object." Out of these instructions has grown up, in the seventy subsequent years, one of the great museums of the world—a most notable center of work in ethnology and related fields as well as in zoology and botany.

For nearly two decades Baird was a most prolific writer in ornithology. In his efforts to clear up tangled and useless synonymy and to ensure accuracy in the recognition of species, he departed widely from the loose and general type of description by using a particular individual and then indicating with precision any deviations due to age, sex, geographical separation or other influences which might appear in other specimens. Such minute exactness made the definition of local subspecies possible, and went far toward establishing the theory that whatever other factors may occur in evolution, changes due to separating barriers constitute a main element in the differentiation of actual species. Many species of animals and plants will be found to vary interminably if deviations can be protected and segregated from interbreeding with the main stock. But in nature, as a rule, small or even large variations receive short shrift, no matter how important they might become in the farm, the garden or the greenhouse. Moreover, however wide the fluctuation, new forms are not species until they have "stood." As a matter of fact, for an intelligent discussion

of the origin of species we need in these days a fresh definition. Let me suggest that a species of animal or plant is a definable form which has run the gauntlet of the ages, struggling constantly for existence, and yet has *endured* Variations of many sorts take place through readjustment of character units, but no product of man's protection and scientific ingenuity is properly to be called a "species" until tested in the race of life, however much it may resemble nature's product. It is of course as "natural" as a true species, but still untested in the matter of endurance in the open.

Baird was not a theorist and did not worry much over the origin of forms; much of his work antedated Darwin's illuminations He described what he saw, and in such fashion that no subsequent observer had any doubt as to what he meant. This persistence in accuracy is the foundation of the Baird School of Ornithology, so ably represented by men like Elliott Coues, Robert Ridgway, John Cassin, Thomas M. Brewer and the rest. In related fields, among others who in some degree caught inspiration from him were Theodore Gill, G. Brown Goode, William H. Dall, Leonhard Stejneger, Tarleton H. Bean, Richard Rathbun, Charles H Gilbert, Otis T. Mason and Frederic A. Lucas. These also did him lifelong homage; lovingly we called him "the grandfather of us all."

In the later expansion and development of the National Museum, Baird took endless and intelligent pains. Nevertheless, as the details of his management are so well known to my hearers and have been so fully described by G. Brown Goode, Dall, Theodore D. A Cockerell and Charles F. Holder, I need not touch on them here. At the same time, no account of Baird's life is possible without special mention of G. Brown Goode, his most distinguished assistant, a scientific student of unique range of knowledge, compelling personal charm, and a degree of executive ability scarcely inferior to that of the chief himself.

The third stage in Baird's career may be dated from the organization of the United States Commission of Fish and Fisheries in 1871, when, in addition to his other duties, he was chosen by President Grant as the first incumbent of a new and wide-ranging responsibility. This position, honorary and without salary so far as Baird himself was concerned, brought his knowledge and influence into the direct service of the government, while the effort further constituted a most effective move for the preservation of wild life. It moreover gave him a vastly increased opportunity to assist young naturalists and to develop in the aggregate more research than he would personally have accomplished had he refrained from

executive burdens. Referring to his own scientific work, he once remarked to me: "Have I not done my share already?"

Says Dr. Holder:

> The appointment of Baird to this unremunerative position marked an epoch in the development of economic science in America, and the growth and evolution of the United States Fish Commission alone shows better than anything else the comprehensive views of its chief and his remarkable grasp upon questions requiring the highest powers of a systematist His work showed that he was an organizer and administrator of the highest rank For twelve years he devoted his energies to the arduous labors of the United States Fish Commission He constructed the entire framework of the new department, and organized it under the following general plan: To prosecute investigations on the subject of the diminution of valuable fishes with the view of ascertaining whether any and what diminution in the number of food fishes of the coast and lakes of the United States has taken place, and, if so, to what cause the same is due and also whether any and what productive, prohibitory or precautionary measures should be adopted in the premises and to report the same to Congress.

The operations of the Fish Commission, modest at first, and confined to investigation along the Atlantic seaboard, soon expanded in many directions. Among these I may include:

A complete study of fishery methods, with collections of examples of nets, traps, spears and other devices of whatever order; the gathering of statistics of fisheries throughout the country; the scientific identification of all available species of fishes, with records of their geographical distribution; monographic reviews of different groups of fishes; the creation of fish hatcheries wherever practicable, with the distribution of spawn of young fishes in various waters, and to different parts of the world; the introduction of desirable new fishes from different parts of the United States and from Europe, and fish protection in all its aspects as well as the study of the various parasites, worms, crustaceans and protozoans which attack or infest fishes.

Most conspicuous of the efforts of exploration has been the work of the "Albatross," a naval vessel adapted for deep-sea dredging by the use of the beam trawl. In this way the deep-sea fauna of the Atlantic and Pacific coasts of North America has been explored, as also that of Hawaii, the Philippines and Japan. Material for the "Oceanic Ichthyology" of Goode and Bean, one of the most important contributions to our knowledge of abyssal life, was drawn primarily from the work of the "Albatross."

In the acclimatization of fishes, especially successful has been the transfer to the Pacific Coast from Potomac River of the shad (*Alosa sapidissima*), the striped bass (*Roccus lineatus*) and two species of catfish (*Ameiurus nebulosus* and *Ameiurus catus*), all of which are more abundant in their new surroundings than in Atlan-

tic rivers, their original home. In addition, the large-mouthed black bass (*Micropterus salmoides*) has been placed in many ponds along with a species of sunfish (*Lepomis incisor*) on which it may feed. The crappie (*Pomoxis annularis*) is now common in the Columbia River. In many lakes of the Sierra Nevada the eastern brook trout (*Salvelinus fontinalis*), the European or brown trout (*Salmo fario*) and the Mackinaw trout of the Great Lakes (*Cristivomer namaycush*) are also well established.

In return, the California Shasta rainbow (*Salmo shasta*) and other western forms find themselves thoroughly at home in the Great Lakes and elsewhere in the east. These American trout have been also established in Europe. In the market at Arlon in Luxembourg, for instance, I saw the Shasta rainbow, and the yellow-fin trout of Colorado (*Salmo macdonaldi*) has been naturalized in mountain streams of France. Still more surprising, I once found the common eastern sunfish or pumpkin-seed (*Eupomotis gibbosus*) in the Rialto market at Venice. But the introduction of the carp (*Cyprinus carpio*) into the United States was on the whole unfortunate, it being of low grade as food, rooting like a pig in the bottom of lakes and ponds, thereby keeping the water turbid.

With the growth and expansion of the Fish Commission came ultimately its change of name to the Bureau of Fisheries, and its transfer from independent existence to the Department of Commerce. To its headship Professor Goode succeeded in 1887. Since his death in 1896, the work has grown steadily in importance along lines of the original initiative, for the most part under wise direction. Its value, both to science and to human welfare, has been adequately demonstrated and its work has met with deserved appreciation.

Soon after the creation of the commission, Baird recognized the need of a marine laboratory where fishes and other sea forms could be systematically studied in life. Casting about for a location, he took his little steamer, the "Blue Light," the modest precursor of the useful "Fish Hawk" and the commodious and efficient "Albatross," to Wood's Hole in Massachusetts, then to Noank, Connecticut, and at last back to Wood's Hole, when the laboratory became, as Dr. Charles O Whitman asserted, the lineal descendant of Agassiz's school at Penikese, conducted in the summers of 1873 and 1874.

For my own part, I first came under Baird's influence in 1874. Visiting Noank, I found the professor absent, but Goode, Richard Rathbun, a classmate of mine at Cornell, Professor Verrill, of Yale, and Alpheus Hyatt were there, busy making studies and collections. The laboratory at Wood's Hole, modestly opened next sum-

mer under such auspices, naturally flourished, becoming in a few years one of the best known and most fruitful marine stations of the world. I remember well Agassiz's delight in hearing one day from Baird that he had caught at Wood's Hole the rare spearfish of the Mediterranean, *Tetrapturus imperator*.

My first connection with the Smithsonian and the Fish Commission occurred in 1876, when I asked for the loan of a "Baird seine," one of the inventor's many devices, adapted for catching minnows and darters In company with a keen-eyed lad, Charles Henry Gilbert, from that time a life-long associate, I ventured into the virgin field of Upper Georgia, a great state in which fishes had never been studied by any one. Baird now encouraged me to take up some one family and write a monograph of it, advice which I followed with several groups in turn. Dr. Coues suggested also that I should enter into scientific partnership with my best student rather than to attempt the heavy work as helper to some older man. "Jordan and Gilbert" accordingly set to work, and in 1882 developed a "Synopsis of the fishes of North America."

In 1880, Professor Baird sent me and Gilbert (as assistant) for a year's study of the fishes and fisheries of the Pacific Coast, under the joint auspices of the Census Bureau and the Fish Commission, an opportunity of the greatest value in the training of us both. In later expeditions under Baird's direction and with the cooperation of Professor Goode, I visited the Florida Keys and Havana, the coast from Pensacola to New Orleans and Galveston, the rivers from the Potomac to the Alabama, Tennessee and Cumberland, and those from the Des Moines to the Rio Grande, still later, Colorado, Utah and the Yellowstone Park. For all such expeditions by myself and my associates, the Smithsonian furnished nets and tanks, and paid actual expenses, no more. On these terms I was able to secure the best of service from devoted young men, such as Gilbert, Evermann, Swain, Jenkins, Meek, Fesler and Davis, whereas, had salaries been paid, the work would have been obstructed by insistence from greedy nephews of greedy congressmen. The spoils system was rampant in the years following the civil war, interfering with the accuracy and sanity of all government work, a fact which accounts for the unwillingness of Professor Henry to allow the government any control over the activities of the Smithsonian.

That this danger was real a single incident will show. In 1882, Baird conceived the idea that a naturalist might well be attached to the staff of the commandant of the Yellowstone Park for the purpose of careful observation of the elk, bear, beaver, porcupine and other inhabitants of this wonderful region. He therefore

asked me to suggest a good man, and I named Seth E. Meek, one of my advanced students in Indiana University. Our congressman, Mr. Columbus C. Matson, was at once interested, insisting on his right to nominate if any one from his district was put into public service.

His first candidate, however, could not possibly accept, being confined at the time in the Monroe County jail to expiate the social error of larceny His second choice was a young man from the neighboring county of Morgan, who received the notice of appointment one Sunday morning when he was trying to spur a serious and remonstrant horse through the door of a Martinsville saloon! He afterward sobered up sufficiently to reach the Park, but soon died of alcoholism at Mammoth Hot Springs Baird's excellent plan thus came to nothing

The various ichthyological expeditions were continued in other waters by my colleagues and students, under the direction of successive commissioners. These efforts conformed to Baird's theory of utility in science. Knowledge loses nothing by acquiring human values, and research takes on a certain dignity by serving at once intellectual demands and human necessities

I mention the matter, not for any personal reason, but as an example of the helpful relation Baird sustained on every side toward those he thought in earnest, and who would faithfully carry out any trust assigned. Any one who could really aid in "the increase and diffusion of useful knowledge" was freely called upon, the word "useful" being given its widest meaning

In early days, budding naturalists were housed in the Smithsonian Tower, where for a time some of us did our own cooking. In 1877, while engaged on a report of the fishes of Ohio, I lived there with my artist, Ernest R Copeland, now a physician in Milwaukee, brother of a most promising young naturalist, Herbert Copeland, who had died in Indianapolis the year before. Coming down from my eyrie one early morning I first met Joseph Henry, who appeared suddenly before the museum doors were opened, unaware that Baird's protégés were infesting the building.

As to his students and helpers, voluntary or salaried, Dall's words could be verified by any of us:

> In his relations with his subordinates Baird was admirable. Orders were given quietly and with consideration. His way with the young student was a mixture of fatherly oversight, kindly criticism and careful training. They came to him as to a father confessor, and the half humorous philosophy he installed in his advice was not only healing but wise. He was never profane, no one would have ventured on a risky story in his presence. I have heard that once or twice in thirty-seven years he was known to be angry, but it was regarded as an astounding phenomenon by all who knew him.

One of Baird's most cherished ideals was that of cooperating bureaus of science. He would have the various workers supported or aided by the government join together as associates and friends, not as rivals, in the increase and diffusion of knowledge This meant the development of a special *morale* based on high principles which would give government service a dignity rare in other quarters of the capital. He would weed out all those who, in Cassin's words, "look on Science as a milch cow, rather than as a transcendent goddess." To a large extent he was successful in these aims, and it is not too much to say that in the eighties and nineties government science reached a degree of dignity and effectiveness it had not before possessed.

Of Baird, as of Simon Newcomb, his friend and colleague, it may be said that he left "a record wholly blameless and wholly salutary, whose work added to the only permanent wealth of nations." In the extension and coordination of human experience, in the widening of the boundaries of knowledge and in the attainment of greater exactness in the details, is found the permanent wealth of nations All this constitutes the subject-matter of science, in science also we find the basis for the development of the finest of fine arts, that of human conduct.

AN UNRECOGNIZED FACTOR IN ALTITUDE EFFECTS

By Professor WITHROW MORSE
WEST VIRGINIA UNIVERSITY

THE increasing importance of the aeroplane, coupled with the sensational attempts of the British climbing party to reach the top of Chomolungmo, or Mount Everest, has emphasized the importance of our knowledge of the physiological effects of high altitudes. It is common knowledge that for most persons not accustomed to unusual altitudes a height of that of Pike's Peak in Colorado involves for them discomfort of intensity varying with the individual, physiological states or perhaps, better, pathological conditions which have been defined by Whymper, the Andean climber, as "nausea and vomiting, headaches of the most severe character, feverishness, hemorrhages, lassitude, depression and weakness." It is commonly believed that such conditions are met at more or less definite heights and that location and environmental features have nothing to do with it. The aviator, however, knows that he feels differently in a doldrum from what he feels when he is breasting the wind, and Alpine literature contains many references to the effects of stagnation of air and of temperature. It is to these that we shall turn in this paper.

The writer's attention to this matter was called by his experiences at rather low altitudes in the Wet Mountains of Colorado. In the particular region concerned, two valleys lead westward from the plains to the San Luis Valley, one known as North Creek, which throughout is broad and is protected from the prevailing winds by mountains which stand at 10,000 feet (3,048 meters), forming what in Wales is known as a corry and in mountain literature as CWM —a pocket, the other, known as Middle Creek, is "gun-sight" throughout, with high, rocky, almost perpendicular sides, but with no CWM at its head, having rather a funnel-like debouchment into the highlands to the westward. The sun reaches the depths of the canyon of Middle Creek only from about 10:30 until 2:30 and the wind is moving ceaselessly from the funnel, downward towards the plains. Contrasting this with the condition in North Creek, where the sun shines from an hour after its rise above the artificial horizon to late in the afternoon and where the wind is inhibited by the

high mountain masses, known as Scraggie and others, one sees that environmental conditions are distinct and characteristic.

It is the experience of the writer that there are corresponding physiological states in the two instances, for while he has never experienced the more definite forms of *mal de montagne* as defined by Whymper, whom we have quoted above, he has, at the same time, experienced lassitude, reluctance to take any unnecessary exercise and ennui during the traverse or North Creek, while alertness and vigor is the experience at all times in Middle Creek. The corresponding levels of altitude should guarantee similar feelings, but this is not so. North Creek, being of less abrupt gradient than Middle Creek, should cause less exertion and therefore less altitude effect.

These experiences, *in magna parte,* are reflected in such studies as have come from our great mountaineers.

The earliest mountain literature is that of de Saussure, who, during the years closing the 18th century, carried on researches in the Mont Blanc region of Savoie in France and elsewhere in Switzerland, his home. If one care not to follow the all-absorbing accounts of his life in the Alps in his "Voyages dans les Alpes," he may peruse the more recent volume by Freshfield, the hero of many mountain expeditions, "The Life of Horace de Saussure" (London: Edwin Arnold, 1920). In the climb up Mont Blanc, they ultimately reached the Grand Plateau shown, well, in the picture by Abraham in the *National Geographic Magazine* for August, 1913, and in crossing this expanse of snow—"an oval ravine, as it were, sloping very gently upward for about two miles to the base of a conical peak, the summit of the mountain, its sides being formed by lofty walls of snow-covered rock, its entrance guarded by two almost perpendicular walls and its bottom full of snow that has fallen into it for ages"—the men exhibited all the manifestations of mountain sickness, although they were men inured to the altitudes of the Chamonix region and although the altitude of the Plateau was not of great magnitude. It is the experience of the average climber of Mont Blanc that this particular part of the climb is what gives characteristic physiological effects not met with at even greater heights on the Matterhorn, the Rothhorn and on other mountains of the Alps and which cause the average mountaineer to consider Mont Blanc more difficult of climb than other mountains.

The reader of the Life of Thomas Henry Huxley will recall that Huxley's attempt at Mont Blanc with John Tyndall ended ignominiously at the hut of the Grand Mulets, for the exhausting climb over the flat névé above the hut was too hard for the renowned

scientist, who found too much of London's smoke in his body for strenuous climbs in the higher reaches of the Alps.

In Mallory's account of the reconnaissance of the highest mountain in the world ("Mount Everest, The Reconnaissance, 1921," New York: Longmans, Green and Co., 1922), the effect of heat and stagnant air is described: "We had also been greatly interested by the phenomenon of fatigue. The most surprising fact when we applied our standard of comparison was that we got along better when we remembered to breathe hard and we already suspected what was afterwards established—that it was necessary to adopt a conscious method of breathing deeply for coming down as for going up. Another inference, subsequently confirmed on many occasions, accused the glacier. The mid-day sun had been hot as we crossed it and I seemed to notice some enervating influence which had not affected me elsewhere. It was the glacier that had knocked me out, not the hard work alone, but some malignant quality of the atmosphere which I can neither describe nor explain; and in crossing a glacier during the day I always afterwards observed the same effect, I might feel as fit and fresh as I could wish on the moraine at the side but only succeeded in crossing a glacier without feeling despairing lassitude."

Turning to other parts of the world, we find Edward Whymper in his "Travels" in Ecuador considering similar effects. He was climbing the great cone Chimborazo which rises 21,425 feet above the sea. He had reached 16,000 feet without any signs of illness. "We were all in high spirits, which was to be expected as we had ridden most of the way." The guide, Carrel, an experienced Swiss guide, "selected a position for the second camp with much judgment, at the foot of a wall of lava, which perfectly protected the tent on one side." The results were disastrous "In about an hour, I found myself lying on my back, along with both the Carrels, placed hors de combat and incapable of making the least exertion. We knew that the enemy was upon us and that we were experiencing our first attack of mountain sickness." Inasmuch as this was what Whymper came to Ecuador to find and to study, we can not mete out much sympathy. At this time, Whymper took a dose of potassium chlorate, $KClO_3$, the great oxygen content of which being probably what gives relief, having been introduced by Henderson into mountain medicine during his expedition in Kashmir. However, the use of this drug is of questionable desirability, for 15 grams (half an ounce) have been fatal and even in small amounts, methemoglobin is formed, which actually imitates carbon monoxide in its effects, lowering the oxygen-fixing powers of hemoglobin. The guide, Carrel, adopted another therapeutic agent,

"wine—red wine, when heated and beaten with raw eggs, provided it is drunk while looking over the left shoulder . . .," but Whymper never had the patience to hear the rest of the recipe.

Strikingly similar experiences were felt by Sir Martin Conway in his trips through the mountain lying north and east of Kashmir, in the region of the great K_2, the second highest mountain in the world. "One can lie on one's back and not believe by any conscious discomfort that one is not at sea-level. But let a single gleam of sunlight fall upon the tent and everything is changed. A headache probably appears upon the scene." Again: "The connection between heat, still air and human discomfort at high altitudes is a close one and calls for explanation. A climber is forced to take account of it. In attempting the ascent of a high peak, he should, if possible, approach by a north and south valley so as to win as much shade as possible and then he should endeavor to climb by an exposed ridge rather than by gullies or snow slopes, for thus will he the more probably avoid stagnant air. Finally, he should work in bad weather and by night as much as possible." In his climb up Pioneer Peak, from which he could look out over the sea of peaks from K_2 to India and Mongolia, he spoke of the "terrible heat which the burning rays of the sun poured upon our heads. . . ." There was plenty of air upon the actual ridge and now and again a puff would come down upon us and quicken us into a little life; but for the most part we were in the midst of utter stagnation which made life intolerable" Not only were these experiences felt by Conway, but by Bruce, one of the most remarkable mountaineers of all time, and by the guide from the Alps, Zurbriggen.

Let us turn to some of the physical factors to account for these phenomena.

If the temperature of the tent at sunrise be 10° C., that is, 50° F., the air density will be 0.1247 and if the sun within a few minutes, as well it may, in the higher altitudes, where the thin air permits the full value of the rays to become evident very quickly, endow the air within the tent with a temperature of 20° C., a rise of 10° C., the density has fallen to 0 1204 and at 30° C. (86° F.), another rise of 10°, the density has further fallen to 0.1164. Now the density of the air changing from 0.1247 to 0.1204 is a change similar to what one experiences when estimating the density of air-samples taken a thousand feet apart in altitude and a difference of 8 per cent. as between the air with a density of 0.1247 and 0.1164 is similar to a vertical rise in altitude of over two thousand feet. Hence, if one is resting in a tent at an altitude of, say, 16,000 feet, as in Whymper's case, and the sun shines, increasing the temperature of

the close, static air 20° C., it is equivalent to his being suddenly transported to an altitude of 18,000 feet, with corresponding lower oxygen tension in the air and accompanying lowered oxygen utilization in the body. Accompanying this, sunlight increases the metabolism of the body considerably, making more need for oxygen. Little wonder, then, that the effects of altitude are accentuated!

It is worth while to look farther into the specific procedure which is going on in the case of mountain sickness. Loevenhart has shown at the University of Wisconsin that anoxemia, that is, the want of oxygen, leads to the accumulation of acids in the body. The body is normally slightly alkaline and kept so by a delicate mechanism of chemical nature whereby the phosphates and carbonates of the blood take care of the excess acid as it forms. The carbonic acid of our breath is thrown off, relieving the so-called "alkali reserve," that is, the chemicals just mentioned as protectors against acids and leaving these chemicals to cope with acids which are not volatilized and thrown off, in the breath, of which lactic acid, a normal product of muscular action, is a conspicuous one. The carbonic acid of the blood is never permitted, normally, to accumulate and if there is a sudden production of this compound, as when we start up a hill, the increased acidity of the blood, due to the carbonic acid, comes into contact with the regulatory center of the brain, the so-called "respiratory center," and stimulates it to increased action, and accelerated ventilation of the lungs ensues, that is, we breathe more frequently and more deeply. Hence, the CO_2 is thrown off. Not so, however, with the lactic acid, and the more the muscles work, the more lactic acid there is produced. This acid is taken up by the alkali reserve and the combination is thrown off via the kidneys. If there is excess acid production, this alkali reserve is depleted and may become dangerous. In the disease, diabetes mellitus, there may be plenty of oxygen, but the powers of the body to utilize the oxygen are weakened, so that the result is the same as if there were an oxygen want, and whenever this occurs, the fats, especially, but also the other constituents of the body fail to be oxidized completely to carbonic acid and water; and these acids of incomplete combustion, known familiarly to the physiologist as the aceton series (aceton, aceto-acetic and hydroxy-butyric acid) arise and have to be taken care of by the alkali reserve, which may not be adequate to the task; and hence there is an accumulation of acids, and in the later stages of diabetes, the patient may die of coma or intoxication from the accumulated acids which can not be taken care of by the depleted alkali reserve. These same compounds form in the case of lowered oxygen supply, as in severe exercise and in altitudes where the oxygen

tension is low. In mountain climbing, then, we have the acid test, that is, Can the organism take care of the acids formed while there is not enough supply of alkali reserve to take care of these additional and dangerous acids? There is one other point in regard to the tendency to the accumulation of acid in the blood and that is, as Barcroft and others have shown, the power of the blood to hold oxygen is lessened as one passes from a normal alkaline blood to one where the acids have depleted the alkali reserve. Hence, as one mounts to higher altitudes, the lowered oxygen tension leads to acid formation which lessens the power of the blood to hold oxygen. The heart seeks to compensate for the increased demands made upon it, as Eyster and Meek, also at Wisconsin, have shown recently; for with the heart pumping at 5,900 cubic centimeters at rest, during exercise, it may increase its output to 10,750 cubic centimeters. The actual sickness of mountain "sickness" is undoubtedly due to the heart, for, as workers at Cornell Medical College in New York (Hatcher and Weiss) have demonstrated, the heart has direct relation, by way of the nerves, to vomiting and nausea.

The question is asked whether man will ever be able to climb Everest. Two climbers of the British expedition of 1922 approached to within two city blocks of the top, using oxygen from tanks which they carried with them. An oxygen supply, then, is adequate, but other conditions have to be met with, which will be overcome and we shall read some morning of the conquest of the greatest height on the globe's surface. Whatever may be the solution, it will have to do with what we have called "The Acid Test."

PLANTS WHICH ATTRACT POPULAR ATTENTION[1]

By O. A. STEVENS
AGRICULTURAL COLLEGE, NORTH DAKOTA

FOR several years one duty of the writer has been the identification of numerous plant specimens received at the agricultural college with requests for information concerning them. Naturally, a large proportion of these have been weeds, and the inquiries have been regarding the name, nature and method of eradication. In this group it has been interesting to note the seasonal variations in the plants received. Other variations have been due to publicity which has been given to some particular plant.

Another group of inquiries comes from teachers who have had their pupils prepare collections of plants and wish to have the specimens identified These usually include our common prairie plants or weeds and sometimes bring interesting notes on vernacular names.

Poisonous plants are a never-failing source of interest and fascination. Since North Dakota is a comparatively dry prairie region, mushrooms comprise a very small proportion of specimens received, although a favorable period of weather usually brings a few of them. Stock-poisoning plants, on the other hand, are of much interest, and every year brings a number of cases suspected to be due to poisonous plants. Most commonly the plants submitted are not known to be of poisonous nature. One lot, collected in a marshy place in search of water hemlock, consisted of duckweed, cattail, long-rooted smartweed (*Polygonum emersum*), tall white aster (*Aster paniculatus*) and water parsnip (*Sium cicutaefolium*). Another contained three species of bulrush, marsh marigold (*Caltha*), meadow-rue, meadow-parsnip (*Zizia*), horsetail and a buttercup, in addition to water hemlock, which is the one really to be feared.

In North Dakota the most important poisonous plant is probably the water hemlock (*Cicuta maculata*). Comparatively few cases of stock poisoning have been traced to it and none of human poisoning so far as the writer recalls in his experience in the state. The plant, especially its roots, is one which is known to contain a virulent poison. The roots have a pleasant parsnip-like fragrance,

[1] Photographs by R. C. Corbett, college photographer.

FIGURE 1. FALSE LUPINE

(From pressed specimen.) The stalk at the left has two flowers at the right of the uppermost leaf. The other stalks have young pods, and a mature pod is shown at the right.

and it is not at all strange that occasionally children have made the sad mistake of eating them. The dried plant in hay, however, does not seem to cause trouble, else we should have more trouble with it, as it is common in many low places. The non-poisonous water parsnip (*Sium cicutaefolium*) is much more common here and is extremely similar to water hemlock in general appearance.

At least three species of loco are found in the state, one of them (*Oxytropis lambertii*) abundantly, but they do not seem to cause much trouble, and very little inquiry is received regarding them.

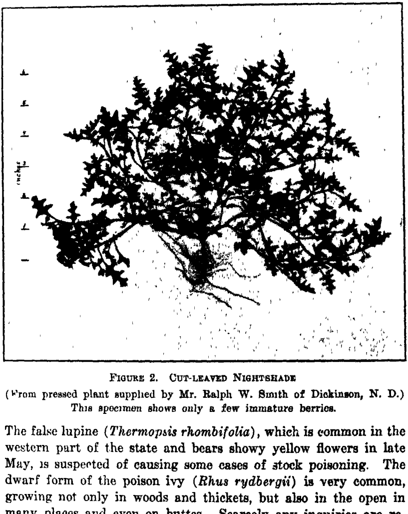


FIGURE 2. CUT-LEAVED NIGHTSHADE
(From pressed plant supplied by Mr. Ralph W. Smith of Dickinson, N. D.)
This specimen shows only a few immature berries.

The false lupine (*Thermopsis rhombifolia*), which is common in the western part of the state and bears showy yellow flowers in late May, is suspected of causing some cases of stock poisoning. The dwarf form of the poison ivy (*Rhus rydbergii*) is very common, growing not only in woods and thickets, but also in the open in many places and even on buttes. Scarcely any inquiries are received regarding it.

Medicinal plants stand in close relation to poisonous ones, and of course many species are on both lists. These have been the source

of but few inquiries, although an occasional ginseng letter is received, the plant being usually the false spikenard (*Aralia nudicaulis*). A few years ago one correspondent was growing a plant which was a sure cure for hog cholera, having been brought from Europe by a farmer. The material was jealously guarded, however, and its identity was not learned.

Perhaps it is a wise provision of nature that people are imbued with an impression that almost any wild berry or mushroom is likely to be poisonous. Species which actually are poisonous are few, but certainly it is safer to leave them alone unless one knows. Regarding the poisonous or edible nature of wild fruits, quite a few inquiries are received. One of the most prominent of these with us is the cut-leaved nightshade (*Solanum triflorum*), which is common especially westward. This species as well as the common black nightshade (*Solanum nigrum*) has been on the poisonous list for a long time. Like so many other species of the family they seem to contain a small amount of poisonous material.

The black nightshade is found occasionally in eastern North Dakota but has not attracted attention. Its berries are eaten by many people and seem rarely if ever to cause ill effects. It may be remarked that the name "deadly nightshade," so frequently applied to this plant, belongs to the species yielding the drug belladonna (*Atropa belladonna*) and is a European plant not found in America.

The cut-leaved nightshade has berries which are somewhat larger than those of the black nightshade, and which remain green in color. Many inquiries are received regarding them, but I have not been able to find any one who has eaten them. Data on their effect are lacking, but some trials made here last year by feeding the berries to sheep gave negative results.

Another fruit which has brought a few inquiries is the wolfberry (*Symphoricarpos occidentalis*). This is a very common native plant growing in woods, thickets, slight depressions or on the open prairie, and bears an abundance of small white berries scattered along its slender branches. One letter received some time ago and an item seen in a newspaper indicated that cases of poisoning had been caused by these berries. No evidence of poisoning from them seems to be on record, but it is possible that a glucoside might be responsible for the trouble. One man informed the writer that he had seen horses eating the fruits.

The sheepberry or black haw of our region (*Viburnum lentago*) also has been the source of a few inquiries. The bush is found frequently in the eastern part of the state. The black berries are sweet and pleasant to the taste in late fall, but contain only a small

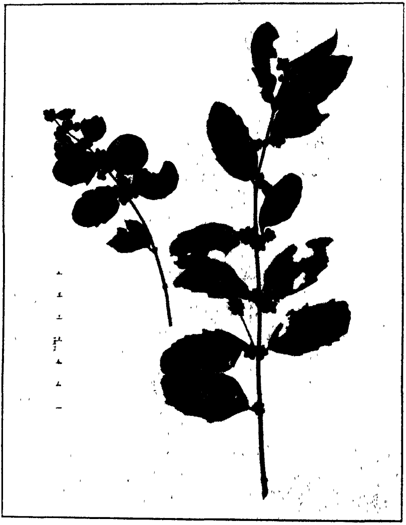


FIGURE 3. WOLFBERRY WITH MATURE FRUITS
The larger branch is from a vigorous bush which reached a height of three feet. The smaller one shows the more common size and position of plants growing in the open.

amount of edible matter. During the past fall several specimens of the berries of carrion flower (*Smilax herbacea*) were received. One correspondent stated that the children had picked them along with wild grapes and wondered what effect they might have upon the jelly. The berries have a not unpleasant taste and probably are harmless. Gilmore states that they were eaten sometimes by the Omaha Indians. The hard, bright red seeds are interesting and would seem to have possible use for ornamental purposes.

Another correspondent sent the subterranean seeds of the hog peanut (*Falcata comosa*) and wished to know the possibility of cultivating them. He had been informed that along the Missouri River they were valued for hog pasture. The slender vines and woodland habit of the plant would seem to preclude their cultivation in any ordinary way, but the writer has found them altogether too prolific in a wild flower bed. These underground seeds grow one in a place on thread-like branches from the nodes of the stems. They are irregular in shape and from two to several times as large as the beans found in the pods of the ordinary flowers. They were used extensively by the Indians, who usually robbed the stores of the wood rats and field mice to secure them. Gilmore states that the Dakota women maintain that they never took them from the mice without leaving some corn or other food in return.

Out of a total of 290 letters with plant specimens for identification during the year ending July 1, 1922, 200 have been concerned with weeds. As a matter of fact it is difficult to classify them exactly, since the letters frequently do not mention the term "weed," and some plants might or might not be so considered. Other plants distinctly not weeds are sent sometimes because of their resemblance to known weeds. Material identified from seeds only has been classified as "seeds examined" and not as plants identified.

The plants identified in these 200 inquiries belonged to 86 different species, of which over one half (47) were received but once. The ones which appeared most commonly and the number of times are listed below:

Quackgrass (*Agropyron repens*)	39
Leafy spurge (*Euphorbia esula*)	19
Goat's beard (*Tragopogon pratensis*)	16
Frenchweed (*Thlaspi arvensis*)	12
Buffalo bur (*Solanum rostratum*)	11
Blue wild lettuce (*Lactuca pulchella*)	11
Prickly lettuce (*Lactuca scariola*)	10
Canada thistle (*Carduus arvensis*)	10
Perennial sow thistle (*Sonchus arvensis*)	10
Tansy mustard (*Sophia intermedia*)	8
Sweet grass (*Savastana odorata*)	7
Western wheatgrass (*Agropyron smithii*)	5
Little sage (*Artemisia frigida*)	5
Prairie thistle (*Carduus undulatus*)	5

FIGURE 4. CARRION FLOWER IN LATE FALL

After the leaves have fallen, the large clusters of berries are conspicuous.

It might appear upon first thought that such a summary would present a fair survey of the weed flora of the state. A careful study, however, shows that while a certain amount of information is furnished by the list, it would be quite misleading to depend upon it without other information. There are many different reasons why weeds attract attention, and neither the abundance nor injury caused by the different species is shown accurately by such a list.

The most recent list (unpublished) of the weeds of the state prepared by the writer contains 226 species. A number of these are introduced plants which have been collected only once or twice and have not become established to any extent, if at all. Others are native plants which might or might not be classed as weeds. In a similar list published eight years ago (now out of print), some of these less common or unimportant ones were omitted, and the total number was 180 species. A bulletin recently published (N. Dak. Exp. Sta. No. 162) includes twenty-nine of the most important weeds, together with seven others often confused with certain of them. Since some weeds have entirely different habits from others, and some are especially troublesome in certain districts, it is not possible to arrange the species in order of their weediness to one's entire satisfaction. Different people have different ideas as to which is the worst, consequently any list of a certain number is quite sure to have one or two which could be dropped out and others substituted without affecting materially the value of the list.

A comparison of the 275 specimens received with the three lists just mentioned gives the following results: About one third of all are included in Bulletin 162. Half as many more belong to the seven secondary species included in the same bulletin. Thus, one half of the total number were covered by this publication. Of the remaining one half, four fifths are in the 180 species list. This leaves twenty-three specimens belonging to twenty-one different species still unaccounted for. Fourteen of these are missing from the 226 species list; they are nearly all native plants which were not regarded as weedy enough to be mentioned.

It may be considered, perhaps, that the list of thirty-six represents a quite successful selection in that it includes half of the total number which occasioned inquiry. A further comparison is of interest. Fourteen species of the thirty-six (nearly one half) are not represented among the inquiries; six others by one specimen only, and three more by two specimens. This probably indicates that the commonest weeds are well known and have not occasioned inquiry, while the questions pertain chiefly to identification of unknown plants. Ten of the species described in Bulletin 162 have been

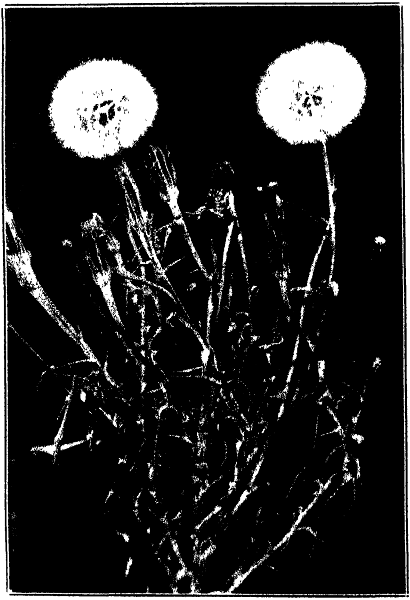


FIGURE 5. GOAT'S BEARD
Showing two expanded fruiting heads, several nearly ready to expand and several naked receptacles from which the fruits have blown.

received five or more times; most of those which have been received fewer times or not at all are among our commonest field weeds.

Why, then, have these ten species been the source of half of the total number of specimens received? These plants are quackgrass, leafy spurge, Frenchweed, blue wild lettuce, prickly lettuce, Canada thistle, sow thistle, sweet grass, western wheatgrass and prairie thistle.

That quackgrass should stand at the head of the list, with twice as many specimens as any other, is due to several reasons. In two or three cases several specimens from different fields were sent and each of these has been counted. The plant is justly feared on account of the difficulty with which it is to be eradicated. Its abundant rootstocks are very characteristic and can not fail to attract the attention of any observing person. But probably the greatest amount of the inquiries are due to the fact that positive identification is difficult. Western wheatgrass is a native plant common all over the state; its flowering spikes and rootstocks are quite similar to those of quackgrass, and the identity of one or the other is a continual question which the weed expert is called upon to settle. Sweet grass is another plant which comes in the same way. Its rootstocks are somewhat like those of quackgrass; its flowering panicles are quite different, but coming very early in the season they are not available for comparison. Neither sweet grass nor western wheatgrass are considered bad weeds, although either may cause some trouble at times.

The case of leafy spurge is difficult to explain satisfactorily. It was found in North Dakota for the first time in 1909. Since that date it has been collected at a number of localities representing a wide distribution over the state and has caused an increasing number of inquiries. This evidence suggests that it has been spreading rapidly, but of its origin and method of distribution we know nothing. Its seeds are not wind blown and have never been found in crop seed samples examined by us during the period covered. The plant is not especially conspicuous, although the pale green bracts of the flower clusters are rather different from any of our other weeds. It is a plant which we have been watching with some concern since it spreads by the roots. These would be likely to attract attention if seen.

Frenchweed is the only one of our most important annual weeds which appears in the list received five or more times. This may be due largely to its ill repute, as it is one of the most troublesome of the mustards. Its seed pods are somewhat conspicuous, and its habit of flowering very early in spring and late in fall is prominent. Often the seedlings are so crowded in certain spots that they make

very little growth On one occasion some of such dwarfed plants were brought in, and when identified the man replied: "But I have Frenchweed all around these." These, he thought, must be something different.

Blue wild lettuce is a very common native perennial which is rather persistent under grain crop farming. It is perhaps the most important of our native weeds, but it has attracted attention more on account of its resemblance to sow thistle. The blue flower heads are quite different from the large yellow ones of sow thistle, but the leaves of the two plants are much alike, especially the small basal ones. The milky sap and persistent roots constitute further similarities. Prickly lettuce also has received attention because of its having been mistaken for sow thistle and will be discussed later in that connection.

Canada thistle has held a prominent place in the weed literature of the United States for many years, and no surprise will be expressed that it appears in the list. The plant has been known by this name for so long that it is probably useless to reiterate here that the name field or creeping thistle which is applied to it in other countries is more appropriate. "Field" is the literal meaning of the specific name arvense which was given to it two hundred years ago by Linnaeus, who remarked that it was one of the worst weeds. Also, it is almost the only one of our true thistles which is a prominent field weed or which has running roots. The common prairie thistle (*Carduus undulatus*) of our region is frequently confused with it, and this fact, rather than its prominence as a weed, accounts for the attention which the native plant has received.

The perennial sow thistle is the one weed which has been given much publicity in the state during the past few years on account of its alarming advance into new territory and the damage caused by it when once established. The number of specimens of the plant which have been received are not at all proportional to the agitation concerning it. This fact is brought out still more strongly by the specimens received from July 1 to August 15, 1922. During that time twenty-seven letters brought prickly lettuce and eleven spiny sow thistle (*Sonchus asper*), an annual species of less importance. Most of these letters inquired whether the plant sent was sow thistle, and not a few cases came as a result of disputes over the identity of the plants.

During the same period only four plants of the perennial sow thistle were received! The writer interprets the evidence as showing that much interest was taken in the question, and many people who were not acquainted with the plant sent specimens of what they thought might be it. The real plant was usually recognized

when found. With two exceptions the prickly lettuce came from localities where the sow thistle either is absent or not common.

During the year eleven different species were received with the inquiry whether they were sow thistle. Of these, spiny sow thistle, gumweed (*Grindelia*), prickly lettuce, false dandelion (*Agoseris*), goat's beard, hawk's beard (*Crepis runcinata*) and yellow rocket (*Barbarea vulgaris*) all have yellow flowers, and those of some of them much resemble those of sow thistle. Why the yellow rocket should have been suspected is difficult to explain, except that it was a new, unknown plant. The other plants sent do not have yellow flowers, but Canada thistle and prairie thistle are prickly, while the leaves of blue wild lettuce and of western lettuce (*Lactuca ludoviciana*) somewhat resemble those of sow thistle.

It is evident that there was much interest in sow thistle, but that it did not result in a large number of specimens of the plant being received. One of the most interesting cases was that of the false dandelion, the root of one plant having been pierced by a rootstock of western wheatgrass. Thus the specimen possessed a large yellow flower head and a running root, two essential characters advertised as distinguishing the species to be looked for.

The remainder of the plants received five or more times are not included in the list of thirty-six weeds in bulletin 162. Scarcely any other plant has attracted more attention than goat's beard, which has been represented to an increasing extent in the correspondence of the last two or three years. The writer believes that this is not because the plant is increasing rapidly, but rather that it is a result of the sow thistle campaign or of a general increase of interest in weeds. The flower heads of goat's beard are much like those of perennial sow thistle, also the plant has a milky sap. Further than this there is little resemblance, but the fruiting heads which expand like a giant dandelion to a diameter of six inches are probably the feature which has attracted most of the attention. Many correspondents have expressed the opinion that it was increasing rapidly and becoming a bad weed. This hardly seems probable, as the plant has been known to occur in the state for many years. Its habit of growth is not such as would indicate a troublesome weed and it is not so reported from other places, although it is a plant of very wide distribution.

Buffalo bur seems to draw about the same amount of attention year after year. It is frequent in the southern part of the state, and appears occasionally elsewhere, probably introduced in crop seed, as its seeds are frequent in millet seed grown farther south. The general appearance of the plant is quite different from that of any of our other species, and this, together with its prickly nature,

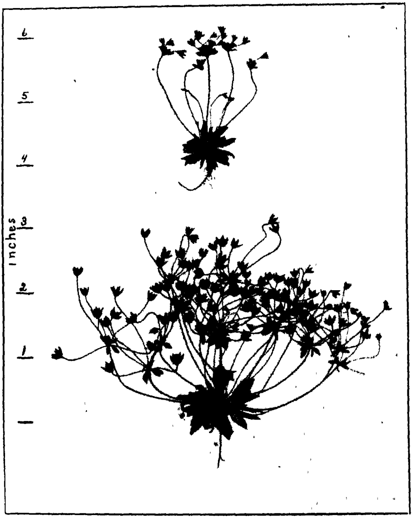


FIGURE 6. ANDROSACE, A PLANT WITHOUT A COMMON NAME
Upper plant represents the early flowering condition (May 6); the lower one has mature seeds (May 23).

is undoubtedly what draws attention to it. There is no evidence that it is increasing in abundance, and it is not at all likely to become a bad weed in this region.

Tansy mustard attains a considerable size and is abundant in places under favorable conditions. It has been suspected of being a bad weed, but this is probably due to the fact that it is conspicuous during a short period of its growth. The appearance of little sage in the list is due to the fact that it is a very common prairie plant, readily seen at any season, and almost certain to be picked up by any one making a random collection of prairie weeds. The fragrance of the plant may have something to do with it also.

Of interest to the writer has been the receipt of several plants which one scarcely would expect to be called weeds. One of these is *Androsace occidentalis,* an early flowering plant which sometimes fairly covers the ground in places, but grows only two to four inches high. The flowers are very inconspicuous, the tiny white corolla being almost entirely hidden by the calyx. A western species (*A. puberulenta*) also has been received. This has somewhat larger flowers which are fairly conspicuous if seen at the proper time.

A surprise of the past summer was *Lavauxia brachycarpa,* one of our evening primroses, which until four years ago was known from only one locality in the state. In 1918 the writer found a few plants at a second place in the same part of the state. During the past summer it was received with the statement that the farmer who brought it in regarded it as a bad weed in the corn field. The plant has a general habit of growth much like a dandelion, the leaves also similar but narrow. The specimen sent was an entire plant with a thick cluster of pods on the crown. When suspended by the root it reminded one of a Portuguese man o'war (*Physalia*). The species was received later from two other localities in a different part of the state, but not specifically as a weed. One specimen of mouse tail (*Myosurus minimus*) was received but without statement as to whether it was regarded as a weed. This, also is an insignificant plant which is rare in this state.

In 1917 North Dakota began a campaign for the eradication of the common barberry, which is regarded as an essential alternate host for the black-stem rust of wheat. Since 1919 this work has been continued by the United States Department of Agriculture At first, efforts were directed against the known large plantings of hedges and bushes, and to a canvass of towns. Since 1919 farm-to-farm surveys have been carried on in 37 counties, with the result that a surprising number of bushes have been found in a state which was believed by most people to have but few of the plants.

Thus the question has received a very wide publicity, and hundreds of people have become curious to see this plant of which they have heard so much.

One of the general accusations against weeds is that they carry diseases of cultivated plants. In this respect barberry is a weed, and the writer's experience is that it is so classed by the majority of the people. In the past five years he has conducted weed exhibits at county fairs in ten counties and many times a day the question was asked, "Have you got a specimen of that barberry bush?" Very often that was the one weed they wished to see.

As in the case of sow thistle, specimens of various other shrubs have been received with the inquiry as to whether they might be barberry. During the year in question these included wild rose, wild olive (*Elaeagnus argentea*), wild liquorice (*Glycyrrhiza lepidota*), dogwood (*Cornus*), buffalo berry (*Lepargyrea argentea*), prickly ash (*Xanthoxylum*) and red haw (*Crataegus*). One specimen of common barberry was received. One might think that a wild rose would be known to every one. Be that as it may, our plants are quite subject to a species of rust (*Earlea speciosa*) which produces conspicuous masses of cluster cups on the leaves and young stems, and it scarcely is strange that they should be a source of suspicion. The red haw, likewise, bears upon its leaves the cluster cups of the cedar rust (*Gymnosporangium*). The wild liquorice very often has its leaves completely covered with the brown spores of its particular rust. The leaves of wild olive and buffalo berry are covered with scales which give them somewhat of a rusty appearance. The prickly ash at least has thorns and small yellow flowers, but no special reason is apparent for dogwood.

We see from this survey that plants attract attention from a variety of reasons, and that the number of specimens received with inquiries may be an index to their abundance or importance; but on the whole it is rather more likely to be an unreliable guide. Publicity given to any particular plant causes suspicion to rest upon others which may have certain points of resemblance to it. Every one must have a "first time" at which he becomes acquainted with a particular plant. After this he notices it readily, and he is quite likely to interpret this as indicating that the plant is becoming more common.

CREATIVE EFFORT AS A FACTOR IN HUMAN EVOLUTION

By Professor RALPH E. DANFORTH
UNIVERSITY OF PORTO RICO

UNTIL recently I have considered man of to-day the "missing" link or intermediate link between the ape and the finished man of the future. On fuller study of man and many other animals I am inclined to think man still an ape, with some individuals well started on the road to manhood.

Zoologists often speak of birds as glorified reptiles, and indeed to any one who has worked much on the anatomy and embryology of reptiles and birds the fact is very evident. Similarly, we speak of man as a glorified ape, but here the relation is much closer, for while reptiles, birds, apes and men all belong to the same Phylum Chordata, reptiles belong to the class Reptilia, birds to the class Aves, while ape and man belong not only to the same class Mammalia but also to the same order Primates. Some people are indeed "glorified," but the *average* man, squatting in squalor, is a long-legged, big-brained ape without any glorification.

Most of us think of man as a finished being, different from all the animals, finished and fixed, the same yesterday, to-day and forever. Only one finished man has walked this earth, some centuries ago, to show us what a man is

We speak glibly of *human nature* as though it had been and always would be the same, like some mathematical quantity, yet paleontologists know that but yesterday it was very different, and we may fully expect it to be very different in the future.

Man's *creative efforts* have had much to do with this change, and will have even more to do in future.

Creative effort is the attempt to produce something new, something vital and living. It may express itself through sex or through the mind or heart. Some people seem to have more originality, more creative force than others. All who possess it feel the need of expressing it. Too many waste it.

Nothing can be more useful in making the man of the future than creative effort. Expressed through sex it can accomplish much; expressed through mind and heart it can accomplish just as much; both are needed, but not always of the same individual. Fortunate it is for the individual possessed of abundant creative

vigor that expression of the same through the mind is so satisfying. Study or the exercise of the learning process will not satisfy it. Imitation will not satisfy it. Repetition and recitals will not satisfy it. But efforts to produce either through art or through writing or speaking something new and vital, with the sincere desire and belief that it will produce a real and lasting result for good, these are creative efforts; these, if exercised systematically and regularly and if properly fostered, bring joy and peace to the most ardent creative personality.

Before considering creative effort in the production of the ideal man of the future, all thoughtful people will admit that man's creative efforts and genius have shaped the man of to-day and built our environment and civilization. We have got away from nature pretty far, too far, some think.

The women of the past evidently liked bearded men, with great bushy growths on their faces. Woe unto us men of to-day who like clean, smooth faces! We are thankful, however, that the men of the past had better judgment in selecting smooth-faced, pretty women to be the mothers of the women of to-day. Oh, the hours we spend on shaving, and the venom wasted cussing the dark stubs perpetually menacing the clean face! Fortunately, both sexes were prudent enough to choose mates with increasingly hairless bodies, as the generations flew past, until the being of to-day, with merely rudimentary fur, was produced, and a great advantage gained over our enemies the parasites and dirt It would have been well if the *cheerful disposition* had been as universally sought and reproduced as the smooth body, but fortunately there are many who possess this priceless hereditary trait.

In hundreds of other ways reproduction and selection have made us what we are, mentally, physically and morally, but for the sake of brevity I must pass the subject on to your own fertile minds with the foregoing suggestions, feeling sure that you will all handle it quite adequately.

Other forms of creative genius have done much to vanquish nature, and too often destroy her, and to build our precious civilization. We have built magnificent homes and great cities, and constructed machines and industries concerning which we ourselves constantly marvel. In fact, so great are we, we can not understand our own greatness.

Yet the average man still squats in squalor, or tags along a slave to the will of others and a slave to impulse and whim. What is to be done with all this greatness and with the vastly greater mass of apish impotence?

By his creative efforts man is continually changing things around him, sometimes for better, sometimes for worse. In many

things he has improved on nature: vegetables, grains and fruits are very superior to wild forms from which they were developed. The milch-cow, beef animal and pig have also been made to produce more nearly what man wants of them. On the other hand he has laid waste thousands of miles of park and forest land, stripping, scorching, allowing priceless soil to wash away.

Instead of spreading out and using these fair lands man congests in great masses, paying more for a small lot of city land than would have bought a whole forest before it was spoiled. There he fills the air with dust and smoke, and pays his agents to go out and despoil more remote lands. He can not see far; his atmosphere is so besmirched. He is not interested in far scenes, grand views nor visions of the future.

What is to be done, I repeat, with all this greatness, and with the vastly greater mass of apish impotence?

Creative effort, is the answer, directed comprehensively yet simply—comprehensively enough to include the whole world in its scheme, and the whole future, also, yet always simply, for the simple things are best.

There is to-day creative effort enough in the world to make this world a paradise, and to make of man right speedily an ideal being.

What should man be? What would he most like to be? *That* may he quickly become. What should this world be? *That* man can quickly make it.

We agree that man has done much to make the man of the present, and to fashion the world of the present, and we likewise agree that he can continue to do so for the man of the future and the world of the future. Let us first consider the man of the future and then the world of the future, although in actual practice the two should be attended to simultaneously.

In making the man of the future, why not make him very superior instead of mediocre? Heretofore, we have been satisfied that our offspring should be as ourselves, or we may even have selected mates which we acknowledged to be inferior to ourselves in some respects.

To rapidly improve the race, it is not necessary to overturn social ideals nor to disregard the sacred family relationship, but rather to raise our social ideals to even higher levels and to make even more sacred the family tie.

The sacred marriage privilege belongs only to those worthy of so high an honor. To be a father or a mother one ought first to be pure and strong and intelligent and joyous and thoroughly sound in body and character; and one ought always to have been

so, and to have sprung from parents and grandparents that were so.

Divide a land, like overpopulated, struggling Porto Rico, in which I live, into three parts. Let each of the three parts receive equal favor and care from the government. Let each have its agriculture, its arts and industries, its businesses and education. Let each be improved, made sanitary and benefited in every possible way—in one part the unmarriageable males to live their lives, cultivate their fields, transact their business, study or teach in their schools and colleges, have their societies and "batch it," as men love to do when they are well fed and prosperous, and have plenty of male companions, lots of work to do and business good; the unmarriageable girls and women in another part; they have proved to the world in recent years that they can do everything that man can do, and do it well Agriculture, business, education, art, music, government—everything would flourish in their domain, as in that of the men.

The third part, for the married folk, well stocked from the first—because it would not do to sever bonds already formed—would remain well stocked, although no additions would be made to the lists of the married until the candidates had been passed upon by a triple committee. The sub-committees would be experts in things physical, mental and moral, respectively, and would not only pass upon the individual candidate but also upon his forebears.

The three parts would be securely fenced apart, and the third part would also require a subdividing fence during the lifetime of those already married who could not meet the requirements of the examining committee, in order to prevent any possible contamination of those who had passed the examinations. The third part would become an undivided unit as soon as the undesirable ones within it died. All children would be examined at some time before marriage, and would be either permitted to marry or transferred to their respective unisexual territory. Many minor details and complications arising would be provided for by regulations so kindly and humane as to make living conditions far happier than they actually are now, when critically examined.

As generations succeeded, and the health, intelligence and morals were brought to higher levels under this rigid elimination of sickly, stupid and immoral strains of heredity, the standards of the examining committee could be raised. The optimum rate of increase, also optimum total population might be factors influencing the conditions imposed by the examining committee.

Let us recall that we are considering creative effort as applied consistently to the improvement of man and his world. Having

drawn in outline a plan for improving man himself, let us turn to the world in which he lives.

A tenth part of the constructive thought now being employed building up great industries with their elaborate buildings, complex machinery and vast business organization would, if directed primarily toward creating an ideal environment, make the world we live in so much more beautiful, healthful and altogether joyous that we would hardly recognize the old ball; or, better said, we of the present would again recognize in it the Mother Earth of the Greek poets, transfigured with new loveliness and made safer through advancing culture and enhanced simplicity.

None of the main stream of creative effort has been turned to this purpose; only the ripples and eddies play upon it here and there sporadically. No truly vast, far-reaching and comprehensive effort has been directed on this goal. The goal has been sighted by many a prophet, poet and writer. Too often it has been put in some far-away utopia, and oftener still relegated to a future existence. Yet already more remarkable results than this have been accomplished by man, tasks more truly stupendous. Some of these achievements are of but partial or even doubtful value to the race, yet wonderful.

The beautification and sanitation of the whole world, both town and country, is relatively simple in nature, if vast in extent. Compared with the complexities, intrigues and agonizing intensity of the great war, it is simplicity itself. Its organization and successful prosecution would require no more men, money, brains and effort than any one of the seven greatest businesses in the world, or of the seven greatest governments in the world. Yet which could we spare best—the ideal world or the individual business or governmental organization referred to?

Many, many times the amount of engineering and business achievement have been consummated which would be required to eliminate slum conditions the world over, remove the dust nuisance from town and country, control mosquito and other nuisances of temperate and tropical zones, and restore forests to their rightful places and beauty to each eyesore where the hand of man has shown more zeal than inspiration.

A youthful leader, with the ability and genius of a John D. Rockefeller, could, by devoting his life, organize the men, the brains, the means and the concerted effort, put the movement on a sure foundation, and start it forward and upward with an impetus which eternity itself would never stop.

At the present moment, man has reached a stage in his evolution where he is ready to receive and cooperate with a concerted,

consistent effort to quickly, scientifically and sanely improve the human hereditary stock and the physical environment we live in. The double improvement will react, one part upon the other, the improved environment accelerating the upward evolution of man, and the new-born supermen will appreciate more fully and evaluate more accurately and truly the worldwide movement toward a perfect environment. Then it will require but a few centuries more when every denizen will be a perfect man, perfect in physique, intelligence, ability, absolute joyousness, interest, spirit and every way, and the world about as fine as heaven itself.

It is a long road from the first one-celled organisms—neither plant nor animal, neither protophyte nor protozoan as yet—to the highest organisms of the present, and the voyage has occupied many millions of years. On the tree of life to-day are many things, lovely and unlovely, and among these, here and there, are some buds of great beauty and promise. Are some of these buds really men—or what are they? Will the sun shine upon them, and the breezes blow, and will the needed sustenance be furnished from below and the needed gifts from above, and will they open into flowers of true manhood? Look a moment again at the opening words of this little paper.

THE USE OF TROPICAL LAND AND TROPICAL FORESTS

By Professor H. N. WHITFORD
YALE SCHOOL OF FORESTRY

To judge the productive capacity of any given region involves the consideration of a complex of geographic factors. These can be divided into two groups, phyto-geographic and homo-geographic. The first have to do with the potential possibilities of any given area to produce crops. The second considers the intelligence of man to utilize successfully the natural crop-yielding capacities of the land and an economic pressure that would force him to use this intelligence in order to survive.

There is probably as much arable land in the tropical as in temperate regions. In some tropical regions, where economic pressure due to heavy population forces it, the arable lands are fairly well utilized, but, generally speaking, the agricultural methods are crude and the yields are far below the potential capacity of the soil and climate.

It is generally conceded that the power of the tropical sun to store up energy in the form of agricultural and wood crops is greater than that of temperate sun. This is due to the fact that heat and moisture are available the year round, whereas in temperate regions they are lacking a part of the year. In fully utilized tropical soils, with certain climates, two crops of corn or rice can be raised in a year, each yielding as much as the one crop that is obtained in temperate regions.

An acre of ground in the Hawaiian islands yields per year five times as much cane sugar as does an acre in Louisiana. The ratio of Porto Rico to Louisiana is about 4 to 1 in favor of the former. In comparing crops rich in starch, like potatoes for temperate regions and cassava for tropical regions, we find that the gross yield of the tropical product in tons per acre is two to three times as much as potatoes.

In moist regions of the tropics the cattle raiser has a great advantage over his temperate neighbor engaged in a like operation, for his cattle can feed on rich nutritious grasses the year round, thus saving the expense of harvesting a crop for winter use.

Figures concerning the relative capacity of the two regions to produce crops of timber are inadequate as yet. Such as are avail-

able indicate that in the production of valuable fully stocked stands of hardwoods an acre of ground in the tropics has a capacity of three to four or more acres in temperate regions. Expressing it more concretely, if it takes 100 years to produce a fully stocked stand of oak of a given amount in New England, for instance, the same amount of mahogany can be raised on similar soils in the tropics in 33 years. The ratio between Spanish cedar and oak is estimated as one to four in favor of the former; between balsa wood, a tropical tree, and cottonwood, two very fast-growing trees, it is one to six in favor of the balsa.

The ratios given above indicate that under the equally intelligent direction of man, lands favored with a tropical sun have two or more times as much power annually to produce crops than do lands receiving the energy of a temperate sun.

Actually, however, the average per acre yield of used lands in tropical countries is much below the actual capacity of these lands. This is due to the homo-geographic and not to the phyto-geographic factors. The average intelligence of the native tropical farmer is much below that of the temperate farmer; as will be shown later he is only one step in advance of the stone age of farming. In spite of this, it is believed that if statistics were available they would show that even under unintelligent direction, the used land of the tropics is producing nearly as much per acre as the used lands in temperate climates. Nature makes up for the inefficiency of man

Lack of products of a kind that could not be raised in temperate zone climates, such as cane sugar, bananas, rubber, coffee, cacao, cocoanut, material for cordage and high grade lumber, forced the white man into the tropics. At first he went as a trader depending on the products that the native brought to the markets. As soon as he found that the supply of any particular product obtained in this way did not equal the demand, he furnished capital to raise his own crops, as in the case of sugar, rubber, bananas and coffee. Where nature already provided a crop as lumber, he introduced modern lumbering methods.

Each year finds the economic interdependence of tropical and temperate countries more pronounced. With this the closer utilization of tropical lands is increasing. The question arises whether, if economic pressure demanded, tropical lands could be brought as near their capacity to yield produce as temperate lands. If they could it would mean a great deal to the future economic development of civilization. If an arable acre of ground in the tropics is equal to two acres in the temperate zone, a very conservative estimate, and assuming that the arable area in the tropics is equal to that of temperate regions, it means that, fully utilized, the lands

can furnish twice as much to feed, clothe and house the population of the world as the latter.

One method of increasing the production capacity of tropical lands would be to colonize them with the races from temperate countries. This has not been done successfully. The failure is usually attributed to the climate, but other controllable factors undoubtedly have their effect. One of these is the unhygienic conditions that prevail in the tropics, due to the ignorance of the population, the lack of medical attention and a properly balanced ration. All these reduce the general efficiency of tropical people and raise the mortality rate. What would be the mortality rate and general inefficiency of a temperate community if it were to be cut off from the benefits of the highly organized civilization of today? Would the climate alone save them? One has only to point to the present conditions in Russia as an example. If the per capita distribution of competent medical men were anywhere near the same in the tropics as in temperate countries and fair sanitary measures were enforced, we would hear less about the climate, per se, being an unfavorable one for the temperate man.

The cleaning up of the tropics is one of the principal white man's burdens. Up to date the cleaning up process has been mainly piecemeal with the prime motives of preventing diseases from spreading into temperate regions or to aid the economic and political penetration of the tropics by the white man. Indigenous populations of the tropics have been incidentally improved in this civilizing influence.

In the land-colonization process, material and to some extent political, social and religious improvement is the prime motive that controls migrations from one part of the globe to another. The movement is up hill and not down. Unless it can be demonstrated to the average man with the hoe that he can be benefited materially he is not going to a country with cheaper labor than the one from which he comes. Chinese temperate labor goes to the tropics for two reasons; it finds living conditions in the tropics often better than at home, and other temperate countries, where living conditions are best, are closed to him. For the last reason, Japanese temperate labor is reluctantly colonizing some tropical countries.

Thus it is seen that not one but many factors direct the migration of peoples. Up to the present time the white race has not gone to the tropics as settlers, because temperate lands with political, social, religious advantages are still open to them. When these are closed—they are rapidly being closed—he may find tropical lands more attractive than now.

But we do not have to look to colonization of tropical lands by the white man for their better utilization. Economic pressure

advancing southward from the United States, Europe and to some extent from Japan is doing it. Under the tutelage of temperate man each year finds an improvement in the use of these lands

In tropical countries under control of European governments there has been no general attempt to educate the native population in all lines of endeavor. The assumption is that tropical people generally are not capable of being so educated, though schools of some sort exist. The keynote of such governments is material prosperity, the home governments benefiting largely thereby. In American tropical possessions, education rather than economic exploitation is the keynote of the development. In the Philippines, for instance, for the first time tropical people have been looked upon as being capable of something besides the white man's errand boy. The Filipino is given a chance to show whether he is as much inferior to the white man as the white man generally believes him to be He is being taught to develop himself physically, mentally, morally, agriculturally and industrially. Vocational training, athletics, moral responsibility in the affairs of government, hygienic instruction are all a part of the education of the Filipino. The work is carried on not only in the schools from the primary through high schools and the university, but in all branches of the government. In other words the average Filipino has the same chance to show the stuff that is in him as the American boy.

The first effects of this plan of education was a movement away from the soil, but soon the competition for the "white suit jobs" became so keen and the pay so low that the young men graduating from the high school soon began seeking positions connected with agriculture and other industries. The agricultural college is one of the most popular schools of the university, and is yearly turning out a comparatively large number of students who, working as teachers of agriculture, as managers of plantations and as farmers, are doing much to improve the agricultural possibilities of the soil, bringing it nearer to its potential capacity. In its largest sense this is an experiment not so much in self-government as in teaching a tropical people to control tropical environment. Since the land is the part of the environment that is the chief source of wealth, each year finds it coming nearer to reaching its full productive capacity.

The writer did not realize the significance of the above until Dr. Treub, one-time director of the famous Buitenzorg Botanical Gardens and of the Agriculture Department of Java, made a visit to the Philippines. In conversation the writer asked him why he had come to the Philippines. He replied substantially as follows:

"Your publications showed me that the American government had made great progress in scientific development. Since coming I have found another thing. The attention you have given to the human element by your educational system has convinced me that you are on the right road to success. We, in Java, have developed our lands to as near their fullest capacity as the intelligence of the average native will permit. If we go farther we shall have to increase his efficiency by better education."

The experiment begun in the Philippines is not yet completed, but the results so far obtained show beyond a doubt that if fully carried out a great contribution will have been made in the increased efficiency of tropical people and tropical lands.

The space allowed for this article does not permit of the discussion of all the phases of the present utilization of tropical lands. There are two important primitive customs, however, that stand out above all others The one has to do with the raising of agricultural crops, the other with the utilization of a natural crop, *viz.*, the virgin stands of timber ready to be cut. The economic significance of these two customs has generally been overlooked, and it is for this reason that they are emphasized above all others.

Primitive methods of farming, somewhat allied to those used in the stone age of man, still prevail over large areas in the tropics. Some one has defined a savage as one who depends entirely on the products of the soil and chase that nature provides without any effort on his part other than gathering his food. If this be accepted as the definition, few savages exist in tropical forest regions, for edible plant products are not found in sufficient quantities to sustain any considerable number of people for any length of time. In so far as the evidence goes it seems to be conclusive that farming was one of the earliest acquisitions of mankind. The power to increase the capacity of the soil to yield food was undoubtedly one of the greatest advances made by man in the control of his environment.

The method of farming generally in vogue to-day over large areas in the tropics consists of cutting a patch of forest, burning as much of the felled timber as practicable and then planting the crop and letting it shift for itself. Sometimes the same patch is used two or three years in succession, seldom more, and then the farmer migrates to a new patch and repeats the operation. Different degrees of cultivation of the crop prevail, from the most primitive, where no attempt to weed the crop is made, to the more advanced, where instruments such as the machete or hoe are used. The dividing line between this form of farming and that still more advanced is the use of the plow to prepare the soil for planting.

That the bulk of the staple foods in many tropical countries is raised on fresh virgin soils, that are abandoned temporarily or permanently after a short time, usually not more than three years, without the soil being touched by a plow, is one of the most significant economic problems connected with the present use of land in the tropics. Export figures alone of agricultural products for many tropical countries give a false impression concerning the use of the soil to yield produce, for statistics concerning the value of other products raised and consumed at home are either lacking or if obtainable are not given wide publicity. Thus the leading exports of the Philippines are Manila hemp, coconut products, sugar and tobacco. Yet a rough estimate of the value of all the raw agricultural products raised in these islands show that corn and rice, neither of which is exported, stand in the order named at the head of the list; in fact, they exceed in value all the other unprepared agricultural products of the country. Brazil is noted for its production of coffee, yet it is believed that if statistics were available the value of pastoral products would greatly exceed that of coffee, in fact, estimates of the 1914 productions of the state of Sao Paulo, where most of the exports of coffee originate, show that the annual productive value of pastoral products exceed those of coffee. It is not unlikely that if statistics for the whole of Brazil were available any one of the three principal agricultural crops of Brazil—corn, cassava and beans—would exceed in value the coffee crop.

The significance of this needs to be emphasized, for the bulk of the above-mentioned agricultural crops are raised on land that has never been plowed. Only restricted regions in the tropics are devoted to the so-called commercial tropical products like sugar, tobacco, rice, coffee, cacao and rubber, yet the staple foods that support the population of Central America and tropical South America are corn, cassava and beans, and the bulk of the farming population is engaged in raising these articles just as the majority of the farmers of the United States devote most of their attention to cotton, corn and wheat. In the one case a more primitive and migratory system of farming prevails, in the other the farming is more intensive and stabilized. Corn is one of the principal rations of a large proportion of the people of tropical America. If sufficient quantities of corn can be raised by the primitive methods above described to feed the 80 million people of Central and South American republics, what would be the per acre capacity of the land to raise this crop, were more intensive agricultural methods used? If the economic demand for this product should increase beyond the power of temperate lands to produce it in sufficient quantities, vast areas of arable tropical lands could be utilized to meet this

demand. The fact that under more intensive agricultural methods two crops can be raised annually means that the per acre capacity of tropical lands is double that of temperate lands.

The migratory farm described above begins to fill up with jungle growth even before it is abandoned. Eventually in the place of the virgin forest that formerly existed there arises a second growth jungle, with little economic value, almost entirely different in composition from the original forest.

If, in the early stages of the entrance of the jungle, the vegetation is burned, grasses rather than trees are favored If, as often happens, the fires are repeated, grasslands are the result. In those parts of the tropics where the dry season is more pronounced, grasslands cover large areas where formerly valuable forests prevailed.

Migratory farming in the tropics has been so extensive that enormous areas originally containing heavy forests are now covered with second growth jungle or grasses. Just as one can travel for thousands of miles in temperate regions and see only patches here and there of the original forests, so one can journey through certain regions in tropical countries, along railroads, well-traveled horse or foot trails, and see little of anything else other than what O. Henry calls "amputated scenery." Indeed, if the density of population be taken into consideration, the destruction of the original vegetation of tropical countries is even more extensive than in temperate regions.

Originally the Philippines were practically covered with virgin forests from sea level, and in some places below high tide, to the tops of the highest mountains. To-day more than one half the area of the islands is covered with grasslands or second-growth jungle, most of which is the result of migratory farming begun in prehistoric times and continuing to-day where not controlled.

The observations of the writer and others in various parts of Mexico, Central America and South America show that the migratory farming is annually destroying large areas of the forests.

The tropical migratory system of farming is not practiced because the soil becomes exhausted, as some suppose, but because the farmer is unable to cope with the jungle growth that in a short time creeps into his farm. Strange as it may seem, it is easier for him to make a new farm than "weed" the old one. Either ignorant of the use of the plow, or, if he has such a knowledge, too poor to purchase one and the necessary work animal to go with it, he is forced to pursue the same method handed down to him by his more primitive ancestors. Usually, only when economic conditions force him by the scarcity of virgin forests on which to operate does he

make his farm in second, third or more, rather than in first growth forests. There is no doubt that the fresh soil of the burned virgin forest, improved by the ash constituents, yields better returns than other soils. This is not the reason why he prefers them, but because it is easier to cut and burn the virgin forests than to rid the soil of the much thicker second growth or grass, as the case may be.

Good, bad and indifferent soils prevail in the tropics as elsewhere. The migratory farmer's first consideration is not the quality of the soil, but one which has not yet been covered with thick jungle or grass with which he can not compete. Because he does not use the plow, steep slopes or poor soils with a virgin forest offer more favorable places for his operations than level ground or good soils without virgin forest.

There are a number of reasons why the average conception of the natural and commercial possibilities of the timber products of virgin tropical forests has been erroneous. Not the least of these is the fact that many observers who have written about them have visited those regions where the taller virgin forests of the lower elevations have almost entirely disappeared. The remnants that are left are on the upper slopes or near the tops of the high mountains where the conditions are not as favorable for forests of commercial value as the lower slopes. Such is in general the condition throughout the West Indies and in the more settled parts of other tropical countries. In such regions it is but natural that the capacity of the soil and climate to produce forest growth should be judged by the second-growth forests that are present rather than the original forest which has been destroyed. Again, just as we judge the kind of the agricultural products of tropical countries by the exports that reach temperate regions, so we have come to believe that the only kinds of timber that have value in tropical forests are those that reach our own markets, like mahogany, Spanish cedar, rosewood, teak and others that are used for special purposes and in small quantities when, as a matter of fact, where statistics are available, the quantity of the other woods used in tropical countries greatly exceeds those that are exported for our own use

Wood is bulky and a large share of its final cost to the consumer represents transportation charges. Anything that will reduce transportation costs in this as in other products reduces the final cost to the consumer. Other things being equal, the nearer the forest is to the consuming center the cheaper the cost to the consumer. For this reason, as long as the virgin forests of temperate regions supply sufficient quantities of lumber, there is little or no need of obtaining it from far-away tropical regions. This is one

reason why tropical forests have contributed so little lumber to temperate regions. The little use of tropical woods to-day in temperate countries is not because tropical forests do not contain suitable woods for more general purposes, but because up to the present time the virgin forests of temperate regions have been able to furnish sufficient quantities to meet their own demands and because of the development of a well-organized lumber industry in the temperate regions that has furnished considerable quantities to tropical countries that are rich in forests but poor in lumber. Now that the easily accessible virgin forests of the temperate region have well-nigh disappeared, it is believed that the economic conditions are becoming ripe for the more extensive utilization of tropical woods.

Primitive methods of logging and lumbering as well as agriculture prevail throughout tropical countries. Such methods can be described as "tree" logging in contrast with "forest" logging of the United States and Canada. The crudest form of tree logging is where the log is dragged by hand to the place of consumption or to the nearest means of water transportation. The log may be hewn square or hand sawn where it is felled. In either case the bulk is reduced and can be transported easier. A step in advance is the use of animals for transporting round or squared logs or boards. The introduction of steam for transporting logs from the forest to the mill for sawing and all devices for handling the finished product made possible "forest" or industrial logging. While the more primitive methods are still best suited to certain classes of forest, especially those with small trees, those covering small areas and where only a few of the many species in the forest are of commercial value, such methods are inadequate to furnish timber in great quantities; consequently, tropical countries rich in forests have generally been poor in lumber and have depended on the products of industrial logging of the temperate regions in part at least.

It has long been contended by some that tropical forests are not adapted to industrial logging. This contention has been due to the erroneous belief, as stated above, that of the many species that make up tropical forests only a few can have commercial value. Tropical hardwood forests contain more tree species per acre than do those of temperate regions. Census of tree species of the Philippines show 80 to 100 species per acre. The estimated number of tree species in the Philippines (120,000 square miles) is 2,600 or about three times as many as in North America, north of Mexico. The hardwood forests of other tropical countries would show similar conditions. While this fact is interesting from a botanical

standpoint it gives a false idea of the commercial importance of the forests. A rough estimate of the standing saw timber of the Philippines is 200 billion board feet; of this 150 billion board feet belong to one family composed of 60 or more tree species. Of these some 12 or 15 tree species form the bulk of the timber. Moreover, the wood of all the members of this important family of trees can be grouped into three classes, *viz*, comparatively light hardwoods, not durable in contact with the ground, but as easily worked and as durable as pine, that are used for light construction work. They are estimated to comprise about half the standing timber of the Philippines. The second group of woods are moderately hard that are used for heavier construction work not in contact with the ground, and comprise perhaps 40 billion feet of the standing timber. The third group are hard, heavy and durable timbers and are used mostly for construction work where great durability is required. The primitive methods of logging used in the Philippines previous to American occupation were unable to supply the demand for lumber caused by the awakened industrial development that followed. An examination of the forests showed that they were suitable for industrial logging and milling. As a result such methods were introduced and not only was the increased demand met, but sufficient quantities were produced to allow the beginnings of a comparatively large export trade.

The writer has attempted to show that, due to the full-time working of nature's chemical laboratory, the good old mother earth of tropical regions is able to store up two or more times as much energy annually in the form of useful plant products as are temperate regions, and that, while to-day primitive methods prevail in the utilization of these products, each year economic pressure proceeding mainly southward from the more progressive temperate nations to the north is forcing the better utilization of the soil. The economic penetration of the white man into the tropics in search of raw materials is forcing him to better control the environment that is new to him, both to enable him to live there and to protect the nations from which he comes from the diseases that find a more favorable environment there. Civilized temperate man has made great strides in controlling the environment in which he lives. He has built and heated houses to control the rigors of winter. He has invented means of rapid transportation that will take him to cooler climates in summer and warmer climates in winter. Is it too much to expect that eventually he will be able to construct homes in the tropics that can be cooled to the proper degree of thermal conditions? Also in most parts of the tropics cool highlands that offer favorable places for recuperation are within easy reach of the more

torrid heat of the low altitudes. With air transportation better developed, truly temperate highland tropics will be easily accessible.

Attention has been called to the possibilities of increasing the all-round efficiency of tropical people as illustrated by the educational experiment now going on in the Philippines. While independent tropical nations can not be directly improved in this way, yet the indirect influence of temperate culture on these nations is not inconsiderable It is felt by the example of temperate colonists that are reaching some of these countries in increasing quantities, by the increasing numbers of young men and women who finish their education in the schools of the United States and European nations, by industrial organizations of temperate nations operating in them, and by the work of such organizations as the Rockefeller Institute and others.

HOT WAVES, HOT WINDS AND CHINOOK WINDS IN THE UNITED STATES

By Professor ROBERT DeC. WARD
HARVARD UNIVERSITY

I. Hot Waves

Introduction.—Spells of excessively hot weather, occurring at irregular intervals and lasting for varying periods of time, are characteristic of the summers of the central and eastern United States, especially of the great Mississippi lowland, of the Ohio Valley region, and eastward even to the immediate Atlantic coast. Such periods of extreme heat, known as hot waves, warm waves, hot spells or heated terms, are the antithesis of the cold waves of winter. Both are typical American phenomena. Both are associated with certain well-defined pressure-types. Both have many critical physiological and economic effects. Both are developed to a remarkable degree of intensity and frequency in the eastern United States. Both need consideration in any discussion of United States climatology.[1]

Definition of a Hot Wave

Any spell of uncomfortably hot weather in late spring, summer or early autumn lasting more than a day or so is likely to be popularly spoken of as a hot wave. The longer the hot weather lasts and the more excessive the heat, the more fully is it thought to

[1] Reference may here be made to the following general discussions of hot waves: Burrows, Alvin T.: "Hot Waves," *Yearbook U. S. Dept. of Agriculture for 1900*, 8vo, Washington, D. C., 1901, pp. 325–336, with charts; Henry, Alfred J.: "Climatology of the United States," *U. S. Weather Bureau Bulletin Q*, 4to, Washington, D. C., 1906; "Weather Forecasting in the United States," by a Board composed of Alfred J. Henry, Edward H. Bowie, Henry J. Cox and Harry C. Frankenfield. *U. S. Weather Bureau No. 583*, 8vo, Washington, D. C., 1916, pp. 370, Figs. 199 (p. 290, and elsewhere, on hot waves). There have been numerous discussions of the conditions and characteristics of individual hot waves, among which the following may be mentioned: Garriott, E. B.: "The warm waves of July and August, 1892; *Month. Wea. Rev.*, Vol. 20, 1892, pp. 223–224; Phillips, W. F. R.: "Sunstroke weather of August, 1896," *ibid.*, Vol. 24, 1896, pp. 409–413; "The hot wave of July, 1898," *ibid.*, Vol. 26, July, 1898 (with charts VIII–XII); Henry, Alfred J.: "The hot weather of August, 1900," *ibid.*, Vol. 28, 1900, pp. 333–336 (also contains useful general information on hot waves); *idem*: "Hot spell of August, 1918," *ibid.*, Vol. 46, 1918, pp. 361–363.

deserve the name. There has never been an official definition of a hot wave by the United States Weather Bureau, as in the case of a cold wave. According to Burrows, a hot wave is a period of three or more consecutive days on which the maximum temperatures reach or exceed 90°.[3] This may perhaps serve well as a rigid limitation for meteorological use, but in the present discussion, which concerns the larger characteristics and relations of hot spells from their climatic viewpoint, no such clean-cut definition is necessary.

General Description of a Hot Wave in the Eastern United States

As a weak cyclonic depression moves slowly eastward across the northern tier of states, usually over the Great Lakes and down the St. Lawrence Valley, the southerly and southwesterly winds that prevail in front of it, coming from warmer latitudes, bring very high temperatures, accompanied by high humidity and generally hazy skies. In the absence of an extended cloud cover, the normal diurnal variation of temperature, under the high and powerful summer sun, may carry the thermometer well up into the 90's, and even to 100° or over in the early afternoon hours. The night in a typical hot wave is likely to bring comparatively little relief, except in the mountains and on the coast. The importation of heat from warm southern latitudes continues with the northward drift of the air while the sun is below the horizon, and nocturnal radiation is reduced in the presence of the large amount of water vapor in the atmosphere.

In the typical cold wave the fall in temperature comes with great rapidity, as the wind shifts from southerly to westerly and northwesterly on the wind-shift line at the rear of the retreating cyclonic storm The cold wind arrives as a sudden blast, at high velocity, and gradually dies down after a day or two. In the case of the American *sirocco*, as the hot wave might well be called after its well-known Italian counterpart, the southerly wind is apt to begin very gently; gradually increases its velocity and brings higher and higher temperatures as the gradients become steeper with the gradual approach of the depression. It is thus characteristic of hot waves that the maximum and the minimum temperatures may both become higher on two or three or more successive days.

Fig. 1 is a reproduction of the thermograph and barograph records at a New England station during a very short hot wave. It illustrates, within five days, conditions preceding, accompanying and following a brief spell of very hot weather in that district. The record begins with moderate temperatures under cloudy skies and easterly winds coming from the Atlantic. The change of wind

[3] Burrows, A. T., *loc. cit.*

to southwest, with the slow eastward drift of an ill-defined summer cyclonic depression, brings a marked diurnal range of temperature under prevailingly fair or clear skies. The temperature belt (enclosed by broken lines) rises as a whole, under cyclonic control, to a high maximum (June 23), which is clearly the result of imported heat plus local warming under sunshine. The high nocturnal tem-

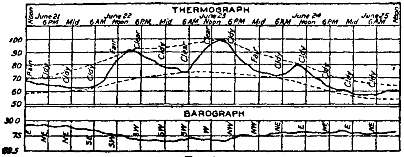


FIG. 1

Typical Instrumental Record during a Hot Wave in the Eastern United States.

peratures (June 22–23) are characteristic. With a shift of wind to the northwest a general fall in temperature takes place. In the case of this particular occurrence, northeast and east winds quickly followed, bringing small diurnal ranges under cloudy skies, the temperatures falling as a whole. The low noon maximum on June 25 is due to these cool northeast winds and clouds. Cool spells of this kind near the coast afford welcome relief after the high temperatures of a preceding hot wave.

A sluggish movement, even at times an almost complete stagnation, of the pressure-conditions is a feature of great importance in the summer weather types of the eastern United States, and accounts for the fact that hot waves sometimes last over the central portions of the country for two or even three weeks with little or no relief in temperature or change in general weather conditions. Two, or even more, hot waves may come in succession with hardly a break between them. On the other hand, such hot spells may last two or three days only. They do not recur with any regularity, but in eastern sections there is often, for a time, a sort of sequence of summer weather types, consisting of a hot spell of two or more days, followed by a cooler period of about the same length, and then by another hot spell. Such a series depends upon a certain temporary regularity in the succession of summer cyclonic depressions drifting eastward across the northern tier of states. At best one severe hot wave may be expected every summer, and occasional summers have many extremely hot spells.

It is characteristic of a severe and prolonged hot wave, which may cover as much as one half of the United States, that it is ac-

companied by a protracted drought. Such precipitation as occurs is in the form of sporadic "heat" thunder-showers, which are usually local, afford temporary relief only and do not benefit large areas. The excessive heat combined with the drought constitutes the unfavorable feature for crops. The eastward movement of the cyclonic centre eventually brings a shift of the wind from southerly and southwesterly to westerly and northwesterly, often accompanied by a series of severe wind-shift line thunderstorms Then comes the summer cool wave, with its brisk northwesterly winds, its bright blue skies and the welcome relief of its refreshingly lower temperatures At other times, a general cyclonic rain may terminate the hot wave, followed by the shift of the wind to west and northwest.

Hot waves are to be looked for in the months from June to September They are as a rule most frequent and most intense in July, but August and September do not lag far behind and are not infrequently characterized by hot waves of great intensity. Indeed, uncomfortably warm spells of a few days' duration, with southerly sirocco winds, occur as early as May, even in New England.

Hot Wave Characteristics in Different Sections of the Eastern United States

As has been pointed out by Burrows, hot waves differ a good deal in different sections of the eastern United States. Over the Great Plains a hot wave not only brings very high maximum temperatures but is often accompanied by special local "hot winds," which are likely to cause serious damage to growing crops. The relative humidity over the plains is less than in eastern sections, and the diurnal range somewhat greater. Hence the oppressiveness of the high temperatures is lessened, and the nocturnal cooling gives a certain amount of relief during the night. East of the plains, as a whole, the maximum temperatures are generally lower, but owing to the higher relative humidity the sensible temperatures are higher and the discomfort and suffering are greater. The hot nights, with minima often over 70°, are especially uncomfortable. Over the Mississippi and Ohio valleys, and eastward to the Atlantic coast, much suffering and illness result, especially in the crowded districts of the large cities, from the prolonged hot spells which occasionally prevail for a week or two at a time. The northeastern section of the United States, including the Great Lakes, has the advantage of being near the most-frequented paths of the weak cyclonic depressions of summer, and therefore of being reached by the cool northwesterly winds on the rear of these disturbances. Because of the small size and slight development of most of these lows, the cool

waves which follow them usually can not advance far to the south, but are able to break the hot spell over the northern sections which are reached by the cool northwesterly winds. Along the Atlantic coast and the shores of the Great Lakes, the cooling effect of the ocean and lake waters, whenever a cyclonic wind or a sea or lake breeze blows onshore, serves to break the monotony and the continuity of many a hot wave which in interior districts may last for days without a break. Further, the northeastern section has the relief afforded by the occasional cloud sheets of the weak cyclonic depressions which drift eastward across the Great Lakes and down the St Lawrence valley, either with or without general rains (see Fig. 1).

The southern states have a somewhat different relation to hot waves They naturally have prevailingly higher summer temperatures. They are farther from the storm tracks. Yet when conditions are favorable they do not escape. Often, however, while warm southerly and southwesterly winds are giving hot wave conditions over the central and northern sections, northerly and northeasterly winds are blowing across Florida and the northern Gulf coast. Florida, with its winds coming from the Atlantic, may then have decidedly lower temperatures than states much farther north. Some years ago, the writer was in northern New England during a severe July hot wave. Even in the New Hampshire mountains the maxima reached 90°, and the nights were uncomfortably warm. A correspondent in Orlando, Florida, wrote as follows of the weather conditions there: "From all I could see in the newspapers, we had about the coolest place in the country down here. It is about 35 miles to the Atlantic Ocean and about 65 miles to the Gulf, and we have a delightful breeze most of the time. After supper, we put on wraps and sit on our front porch, and are comfortable with them on."

Some Economic and Physiological Aspects of Hot Waves

The combination of excessive heat and of a desiccating drought, if prolonged over several days, naturally results in serious damage to crops which may extend over wide areas. If such a hot wave comes at an especially critical period in the life of a staple crop, the financial loss may be much greater than that caused by a severe hurricane It is not alone the accompanying drought which works the injury to growing plants. The baking effect of the high temperatures is in itself disastrous. Beneficial rains within a reasonable time may at least partly make good the injury caused by the drought, but the damage due to the heat may be permanent. Not only is the yield reduced in quantity, but the quality of the crop

is inferior A few hot spells, even if not greatly prolonged, may reduce the local yield in a summer of normal heat as much as 20 or 25 per cent. Fortunately, however, hot waves are not often equally severe over extended areas Hence, while the damage in one state or one section may be considerable, other sections escape the worst effects

Burrows has pointed out that the effects of hot waves as a general rule differ a good deal according to the time at which they come[3] Thus June hot waves are naturally usually less frequent and less intense than those of mid- and late summer. Furthermore, the normal type of rainfall distribution gives a June maximum over a large area of the great agricultural districts of the west—the so-called "Missouri type" of rainfall. Hence, many cereals, like corn, *e g*, are often benefited by high temperatures early in the summer. On the other hand, fruits which ripen in June are often seriously harmed. Crops maturing in the autumn are most liable to be permanently injured by hot waves in July and August. Not only is the heat likely to be greatest then, but the normal season of maximum rainfall has passed, and the scattering and sporadic thundershowers which bring most of such precipitation as occurs are quickly over; do not cool the air effectively or for long, and are soon followed by strong sunshine and active evaporation. Moreover, mid-summer is a very critical time for many cereals Indian corn may be withered by the excessive heat and its growth checked beyond the possibility of later recovery. In the south, a severe hot wave at this season is liable to cause very serious injury to the cotton crop. Pasture grass may be so burned and withered as to be practically useless for feed.

September hot waves, as suggested by Burrows, are likely to drive some standing crops to maturity too quickly, but may, on occasions, help to ripen a backward crop.

An interesting train of economic effects accompanies any prolonged hot wave. A study of the effects associated with the heat and drought of July, 1901, was made by the writer some years ago, and illustrates the variety of economic aspects associated with this type of weather.[4] There was a marked increase in the demand for light-weight summer clothing of all kinds and of vacation supplies. The retail stores quickly sold out their stocks and sent in re-orders to the wholesalers. Thousands of people, suffering from the heat in the large eastern cities, filled trains and steamers on their way to

[3] Burrows, A. T., *loc. cit.*

[4] Ward, R. DeC.: "Some economic aspects of the heat and drought of July, 1901, in the United States," *Bull. Amer. Geogr. Soc.*, Vol. 33, 1901, pp. 338–347.

cooler summer resorts, on the coast and in the mountains. Hotels and boarding-houses were crowded. The demand for ice and for all kinds of cooling summer beverages was tremendous. In order to save themselves the discomfort of shopping, customers sent in their orders by mail, and the large city stores were unable in many cases to keep up with their correspondence, and had to engage extra clerks to handle it. The stock markets responded in a very striking way to the weather conditions. Not only were the prices of wheat, corn and other cereals markedly affected, but so also were the stocks of the great cereal-carrying railroads. So sensitive to weather conditions are the stock markets that the prospect or the occurrence of even light showers in any portion of the hot wave area was immediately reflected in higher quotations The lack of water and of pasturage and the inevitable future high prices of corn led western cattlemen to ship their cattle to market in immense numbers. The result was that the prices of cattle on the hoof, of meat and of hides dropped, and the great packing houses were practically able to dictate their own terms. There was a greatly decreased market demand for meat, and an increased demand for fresh vegetables, so great that the supply was wholly inadequate and in many cities the available stocks of canned vegetables were sold out to meet the needs of customers. The settlement of a strike in some of the Pennsylvania steel mills was delayed because the operatives did not want to go back to work as long as the terrific heat lasted. In many cases manufacturing and industrial plants shut down, and large wholesale and retail concerns in the cities shortened the hours of work in order to give their employees a rest.

Such were some of the more obvious economic effects of one severe and prolonged hot spell. Similar conditions, varying with the locality, with the extent and severity of the heat, and with other factors, may be looked for in any well-marked hot wave.

The physiological effects of hot waves are none the less striking. The high maximum temperatures, the hot nights and, in eastern sections, the high relative humidity at times combine to render the conditions almost insupportable, especially in the crowded districts of the great cities. Heat prostrations, sunstroke and other immediate and direct consequences of the excessive and uniform heat and humidity are common. The number of deaths, and especially those of infants and young children from cholera infantum, may become appallingly large A study of the physiological effects of one prolonged and severe hot spell which occurred over two thirds of the eastern United States at the end of July and in the first part of August, 1896, by Dr W. F. R Phillips, is the only intensive inves-

tigation of this kind available.[5] Dr. Phillips finds that during the three weeks ending August 22, 1896, 2,036 known deaths were directly due to sunstroke, and the list was doubtless far from complete. Probably more than 12,000 cases of varying degrees of severity actually occurred. The significant term "sunstroke weather" has been suggested by Dr Phillips as being appropriate for an especially fatal period during this long hot spell which he studied. As to the direct meteorological cause of sunstroke, the author concludes that neither absolute nor relative humidity are as important as the value of the maximum temperature. He believes that sunstrokes do not occur until the temperature is well above that to which people are accustomed, regardless of other atmospheric conditions. Each locality "has for its native or acclimated inhabitant a special local sunstroke temperature or range of temperature." As a "working hypothesis" it is suggested that "sunstroke becomes imminent during the summer months when the mean temperature of any one day or of several consecutive days becomes equal or nearly equal to the normal maximum temperature for the same period." Or, differently expressed, "the liability to sunstroke increases in proportion as the mean temperature of the day approaches the normal maximum temperature for that day "

Dr. Phillips' conclusions have not been unchallenged. His paper was discussed at a meeting of the American Climatological Association, where it was pointed out that one or two days of high maximum temperatures are less effective in causing sunstroke than continuously high temperatures both day and night for at least two days[6] Henry has pointed out that serious discomfort is seldom felt unless the night temperature remains above 75°.[7] This value, however, probably varies slightly with the locality, being somewhat lower for New England (70°–72°) It has also been pointed out by others that the absence or at any rate great infrequency of sunstrokes in the southwest, where the maximum and the mean temperatures are much higher, militates against Dr. Phillips' views.

Weather Map Conditions Favorable to Hot Waves in the Eastern United States

The weather map types which produce hot waves are just the opposite of those which produce cold waves. The former generally bring the maximum heat on the northern and western outskirts of

[5] Phillips, W. F. R., *loc. cit.*

[6] *Trans. Amer. Cli. Assoc.*, Vol. 13, pp. 234–237.

[7] Henry, Alfred J., *Ann. Rept. Chief of Weather Bureau for 1897*, 4to, Washington, D. C., 1898, p. 264. Also, "Climatology of the United States," pp. 39–45.

an anticyclone, while the cold wave area is to the south and east. Hot waves occur on barometric gradients sloping northward, the high pressure area being over the southeastern United States and the depression in the north or northwest. In cold waves the high is in the northwest or north and the low is to the south or east. The gradient system is thus essentially reversed in the two cases.

As in the case of cold waves, the weather maps which illustrate hot wave conditions differ a good deal from one another in details, and many type maps could be given as illustrations. The essential

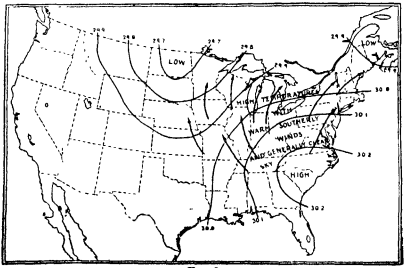


FIG. 2
Hot Wave Type Map for the Eastern United States.

and fundamental condition may, however, be shown in a broadly generalized map, Fig. 2. This map is not a copy of any single daily weather map, but is drawn free-hand to represent a general pressure-distribution which is favorable to the occurrence of hot wave conditions over the eastern United States. The characteristic features are an anticyclonic area over the southeastern states and a moderate depression over the upper Missouri-Mississippi Valley region or the upper lakes. For the production of a prolonged and intense hot wave, this general distribution of pressure must continue, without much change, for a good many days. In other words, there is a sort of slackening up or relative stagnation of the general circulation of the atmosphere. The regular eastward movement of low pressure areas along the northern border is somehow checked, and a general condition of low pressure persists for days over the northwestern, middle western or northern states, instead of the more normal condition of an eastward drift of a series of cyclonic

and anticyclonic areas, with shifting winds and showers or occasional thunderstorms. The southeastern high pressure area, which is really the western margin of the great tropical high pressure belt of the North Atlantic Ocean, also persists, with essentially no interruption or change for days, and seems to act as a barrier to the eastward movement of the cyclonic depression to the north of it. In this type of map, a great flow of warm, southerly winds covers the interior valleys and most of the Atlantic coast. With the slow eastward drifting of a low pressure area across the lakes and thence down the St Lawrence Valley, conditions are favorable for the occurrence of a hot wave well into the northeastern states, and along the Atlantic coast as far as New England. On the other hand, the persistence of the low pressure condition in the northwest favors the occurrence of a hot wave over all the great central valleys. With the eastward movement of the northern cyclonic depression and the disintegration of the southern anticyclone, the hot wave conditions come to an end.

Sources of Heat in a Hot Wave

The excessive heat of a hot wave is due to a combination of several factors. Among these are (1) the importation of air from southern latitudes, (2) effective cumulative warming of the earth's surface and of the lower layers of the atmosphere to a greater height than usual under the strong summer sun, day after day, unhindered by any general cloud-cover, the diurnal heating being in excess of the cooling by nocturnal radiation, and (3) a certain amount of dynamic heating of the descending air under the anticyclone. The cumulative effect of these various contributing causes, when continued for several days, is such that, as Professor Henry has put it, a greater impulse than usual is necessary to put an end to the existing conditions and bring about cooler weather.

Hot Waves in other Parts of the United States

In the preceding discussion, reference has been made only to the hot waves of the broad region east of the Rocky Mountains. These are the most extended and most striking phenomena of the kind in the United States. Yet hot spells are by no means unknown elsewhere, although the conditions of their occurrence and their characteristics are different. It often happens that while a severe and prolonged hot wave is prevailing over the eastern section of the country, other sections, such as the Plateau or the Pacific coast, are abnormally cool. The western mountain and plateau districts have the advantage of active nocturnal radiation in the dry air and under the clear skies of those elevated areas, so that, even when the

days are very hot, the nights are characteristically cool. Long periods of high temperature are, however, normal summer conditions over the less elevated portions of the Plateau Province, and the summer "heat island" of North America centres over the southern portion of this district. The Pacific coast is exempt from the severe and prolonged hot waves which characterize the eastern United States, but occasional short spells of uncomfortable heat occur even on the coast, although the prevalence of onshore winds from the Pacific most of the time ensures this coastal belt unusually cool and temperate summers. The interior valley of California, however, which is well shut off from ocean influences throughout nearly its whole extent, has very hot and dry summers, especially in the south. The conditions are especially uncomfortable when an occasional hot north wind blows. Locally, this wind is not only unusually hot, but also dry and dust-laden and becomes very disagreeable and trying This Californian "norther" is discussed in the following section on hot winds

II. Hot Winds[8]

Description of "Hot Winds"

Reference has been made above to the occasional occurrence, during summer hot waves on the Great Plains, of so-called "hot winds" These are a definite feature of the climate of the eastern slope of the Rocky Mountains. They are a special local development of abnormally hot currents of air within a general flow of hot winds covering a large area. Popularly, the term "hot winds of the plains" has come into use because of the occurrence of these local superheated currents chiefly over the Great Plains region, between the eastern Rocky Mountain foothills and the Mississippi River, and mostly between latitudes 34° and 45° N. They are especially well known in the drier, western parts of the plains. In much less marked development they have been reported as far east

[8] The following references are the most important discussions of hot winds. Most of what here follows is based upon them. Curtis, George E.: "The hot winds of the plains," *7th Biennial Rept. Kansas State Board of Agric.*, Dec., 1890 (contains descriptions of numerous occurrences, and includes weather maps showing hot wave conditions; period covered 1880–1889); Cline, Isaac M.: "Hot winds in Texas, May 29 and 30, 1892," *Amer. Met. Journ.*, Vol. 9, 1892–93, pp. 437–443; *idem*, "Summer hot winds on the Great Plains," *Bull. Phil. Soc. Wash.*, Vol. 12, Jan., 1894, pp. 309–348 (collection of all cases recorded since 1870, illustrated by three typical hot wind maps; also discussion of causes); reprinted in part in *Amer. Met. Journ.*, Vol. 11, 1893–94, pp. 175–176; Henry, Alfred J.: "Climatology of the United States," *Bull. Q, U. S. Weather Bureau*, 4to, 1906, pp. 56–57. Numerous cases of individual occurrences of hot winds are described in the *Monthly Weather Review*.

as Illinois, Wisconsin, Indiana, Michigan and Ohio The hot winds of Kansas and Texas have been most often described and most thoroughly observed and studied.

The chief characteristics of hot winds are their intense heat and their extreme dryness They come in narrow bands of excessively hot winds, ranging from perhaps 100 feet to a half mile or so in width, in a general hot spell, with intermediate belts, varying from a few yards to a few miles in width, of somewhat less terrific heat between them. Hot winds usually last only a few hours, but may recur in rapid succession in the same general locality and have a habit of coming in groups, thus perhaps affecting a territory of a few hundred acres At times, an extended development of hot wind conditions may bring them here and there over a much larger area, embracing most of a state, or even portions of two or three states. Their direction is usually southwesterly or southerly, but occasionally they blow from the southeast and even from the north. Their velocity varies from a gentle breeze to a gale, and they are diurnal in their occurrence, usually dying down toward sunset. The winds may continue to blow throughout the night, but the temperature is then generally lower and more endurable. Very hot nights are, however, by no means unknown. It has been reported in one case that people woke up in the night and thought their houses were on fire. July and August bring most of the hot winds, but they also occur before June and into September.

The dry withering heat in a true hot wind has been compared by many observers to the blast from a hot furnace Temperatures of 100° to 110°, and even higher, are recorded in the shade. On one occasion the temperature rose 7° in 10 minutes on the setting in of a hot wind. The Weather Bureau observer at Leavenworth, Kansas, reported as follows during a hot wind: "At 1 P. M a very hot and extremely dry wind set in from the southwest, feeling as a hot blast from a furnace. It caused the thermometer to rise rapidly, attaining a maximum of 101° at 4 P M. and the humidity dropped suddenly to 17 per cent. This hot wind continued until sundown. It withered and almost burned vegetation and caused a total suspension of outdoor labor during the afternoon."[9] Another observer, at Lawrence, Kansas, reported that the air was excessively dry. The relative humidity fell to 7 per cent. The nights following three days of hot winds were, however, "comparatively cool" (minima 65°–66°). A brief summary of the official meteorological record during the hot winds in Eastern Kansas on September 12, 1882, is given by Henry.[10] Although ordinary psychrometer read-

[9] Quoted by A. J. Henry, *loc. cit.*
[10] *loc. cit.*

ings are by no means accurate, especially when the air is excessively dry, there is no doubt that the percentage of relative humidity falls to 20 per cent., or even less.

Economic and Physiological Aspects of Hot Winds

The excessive heat and dryness of these hot winds, which usually blow with considerable velocity, make them very injurious to all crops. They are veritable scourges, but fortunately do not occur often in their greatest severity. Not only is moisture evaporated from the soil, but growing vegetation is literally dried out as it stands. If the hot winds happen to come at a critical period in the growth of a crop, they may cause heavy damage within a few hours. In one case of recurring hot winds in Kansas some years ago, over 10,000,000 bushels of corn were ruined, and the crop was reduced by 10,000,000 more. Vegetation withers; leaves crumble to dust at the touch; corn, wheat and other cereals look as if they had been scorched by fire; apples are described as being baked while hanging on the trees. So destructive are these winds that during the summer, when the harvest is in a critical stage, reports of hot winds in the west are at once reflected in the future price of wheat, corn and other crops on the exchanges. The moister the soil, as a rule, the less destructive is the hot wind Therefore, any method of conserving soil-moisture tends to lessen the damage. Further, as evaporation depends largely upon the velocity of the wind, wind-breaks, by decreasing the velocity and helping to increase the resistant powers of the soil, are an additional means of protection (Henry).

A case is on record, on the Southern Pacific Railway in Texas, when during severe hot winds the rails expanded to such an extent that they "sprung," and traffic had to be suspended until the rails were shortened and replaced.

If hot wind conditions continue for several days, great suffering to human beings and to animals in the intensely hot, dry air results. The skin becomes dry and parched. One observer, in Texas, reported of the hot winds of May 29–30, 1892, "these hot currents would almost stop one's breathing. I was caught in the centre of one about 100 feet in width, and it was almost insufferable."[11] The dry heat tends to excessive irritability and nervousness in many cases, insomnia being a frequent result. A correspondent writes from western Kansas during a late June hot wave: "We have had no rain for several weeks, with daily temperatures in the 90's and a low humidity. For the last several days I have had my first experience of the 'hot winds.' To-day the furniture in my room is cracking in the dry air. I believe, from my own experience, what

[11] Quoted by I M. Cline. See *Amer. Met. Journ.*, Vol. 9, 1892-93, pp. 437–443.

I formerly doubted, that this dry air inclines to nervousness. Although very tired at night and entirely normal, I often can not get to sleep for an hour or more. And this, for me, is insomnia."

Weather Map Conditions Favorable for Hot Winds

Most hot winds occur with anticyclonic conditions over the southeast and low pressures over the Dakotas, the pressures decreasing northward and northwestward into Canada and the depression being nearly stationary or moving slowly along the eastern Rocky Mountain slope and eastward. Under these conditions, the general winds over the plains are southerly and southwesterly, the velocity being greater the steeper the gradient. Occasionally the depression develops over the eastern slope of the Rocky Mountains, and usually there is a trough or V-formation elongated towards the south and southwest from the northern low. Hot winds are also associated with secondary cyclones at the southern extremity of V-shaped depressions which are traveling eastward along the northern boundary of the United States. In view of these relations to low pressure systems, it is natural that hot wind conditions should gradually move eastward with the eastward progression of the general pressure distribution upon which they depend. In connection with any attempt to study the weather map conditions of hot wind occurrence, it must be remembered that the maps present the facts at one moment only (8 A. M., Eastern Standard Time), in each 24 hour interval. The wind directions and the temperatures shown on the maps at the various stations are therefore unlikely to be those observed while the hot winds were blowing at those stations.

Cause of the Excessive Heat and Dryness of Hot Winds

There has been a good deal of discussion as to the fundamental cause of the extreme heat and the very low relative humidity characteristic of the true "hot winds" of the plains. One group of writers, among whom are Professor W. M. Davis[12] and Dr. I. M. Cline,[13] holds that these winds have a special and peculiar intensity of heat and dryness which distinguishes them from the general hot wave in which they occur. This characteristic is attributed not simply to the heat imported by the horizontal flow of the warm, southerly winds but to the presence of descending currents from a considerable height, starting at fairly high temperatures and then warmed adiabatically by compression during their descent. In

[12] Davis, William Morris: "Elementary Meteorology," 8vo, Boston, 1894, p. 233.

[13] Cline, I. M., *loc. cit.*

other words, they are somewhat similar to *chinook* or *foehn* winds. There are difficulties in accepting this theory, for it is not easy to see how such superheated, and therefore light, local currents of air can be forced down, over extended level plains, into a general body of air which is cooler, and therefore heavier, than they are If the initial downward impulse is present, it is conceivable that the momentum of the descending air may be sufficient to carry the "hot wind" currents below the level of their equilibrium. As evidence of such dynamic heating, it has been pointed out that there have been numerous cases in which the temperature was lower and the humidity higher over the districts to the south of the hot wind area, and that hot winds have occurred at night and after rain. It would therefore seem as if local surface warming of the air in a hot wind could not fully account for the heat and dryness. Dr. Cline believes that the dry air, which has been dynamically heated, is carried forward aloft faster than below, and descends here and there through moister and less dense air below, which rises and forms the scattering clouds often observed.

The second group of writers, among whom are Professor A. J. Henry and the late George E. Curtis, holds that the local heating of the dry earth's surface under clear skies and intense insolation is a sufficient explanation of the heat and dryness of the hot winds. It is pointed out that hot winds do not occur when the soil is moist; that rains quickly bring them to an end, and that they are essentially diurnal phenomena. Favorable local conditions, both of temperature and of moisture, doubtless play a part.

The question, which of these two views is the correct one, need not be debated here. More complete observations of these interesting phenomena, and especially more data from the free air, will in time lead to a fuller understanding.

It is clear that hot winds will always continue to be a serious climatic handicap over the districts in which they occur. Perhaps, eventually, with improved methods of conserving soil moisture and with the planting of windbreaks, some of the blighting effects of these winds upon growing crops will be somewhat mitigated.

III. Chinook Winds[14]

Description of a Chinook Wind

Picture to yourself a wild waste of snow, wind-beaten and blizzard-furrowed until the vast expanse resembles a billowy white sea. The frigid air, blowing half a gale, is filled with needle-like snow and ice crystals which sting

[14] In addition to the brief discussions in the meteorological text-books, reference may be made to the following for further details: Harrington, Mark W.: "The chinook winds," *Amer. Met. Journ.*, Vol. 3, 1886–87, pp. 330–338, 467–475, 576–523; Hazen, Henry A.: "Chinook winds," *Month. Wea. Rev.*,

the flesh like the bites of poisonous insects, and sift through the finest crevices. . . . Great herds of range cattle, which roam at will and thrive on the nutritious grasses indigenous to the northern slope, wander aimlessly here and there, or more frequently drift with the wind in vain attempts to find food and shelter; moaning in distress from cold and hunger, their noses hung with bloody icicles, their legs galled and bleeding from breaking the hard snow crust as they travel. . . . Would the chinook never come? The wind veered and backed, now howling as if in derision, and anon becoming calm, as if in contemplation of the desolation on the face of nature, while the poor dumb animals continued their ceaseless tramp, crying with pain and starvation. At last, on December 1, at about the hour of sunset, there was a change which experienced plainsmen interpreted as favorable to the coming of the warm southwest wind At sunset the temperature was only —13°, the air scarcely in motion, but occasionally seemed to descend from overhead. Over the mountains in the southwest a great bank of black clouds hung, dark and awesome, whose wide expanse was unbroken by line or break, only at the upper edge, the curled and serrated cloud, blown into tatters by wind, was seen to be the advance courier of the long-prayed-for chinook. How eagerly we watched its approach! How we strained our hearing for the first welcome sigh of the gentle breath! But it was not until 11.35 P. M. that the first influence was felt First, a puff of heat, summer-like in comparison with what had existed for two weeks, and we run to our instrument shelter to observe the temperature Up goes the mercury, 34° in seven minutes. Now the wind has come with a 25-mile velocity. Now the cattle stop travelling, and with muzzles turned toward the wind, low with satisfaction. Weary with two weeks standing on their feet they lie down in the snow, for they know that their salvation has come: that now their bodies will not freeze to the ground.

The wind increases in strength and warmth; it blows now in one steady roar; the temperature has risen to 38°; the great expanse of snow 30 inches deep on a level is becoming damp and honeycombed by the hot wind.

Twelve hours afterward there are bare, brown hills everywhere; the plains are covered with floods of water. In a few days the wind will evaporate the moisture, and the roads will be dry and hard. Were it not for the chinook winds the northern slope country would not be habitable, nor could domestic animals survive the winters.[15]

There have been many general accounts of chinook winds in the United States, but few, if any, first-hand descriptions have been printed as vivid, as complete and as accurate as the one just quoted, written by the Voluntary Observer of the Weather Bureau at Kip, Montana, after a well-marked occurrence of this phenomenon in November, 1896.

Vol. 16, 1888, pp. 19–20; Ballou, Howard H.: "The chinook wind," *Amer. Met. Journ.*, Vol. 9, 1892–93, pp. 541–547 (gives short bibliography); Burrows, Alvin T.: "The chinook winds," *Yearbook U. S. Dept. of Agriculture, 1901;* reprinted in *Journ. Geogr.*, Vol. 2, 1903, pp. 124–136 (a fairly full discussion, with charts and diagrams); Henry, Alfred J.: "Climatology of the United States," *U. S. Weather Bureau Bulletin Q*, 4to, Washington, D. C., 1906, pp. 72–73; Abbe, Cleveland: "The wet and dry chinooks," *Month. Wea. Rev.*, Vol. 35, 1907, pp. 176–177; Bavendick, F. J.: "Blizzards and Chinooks of the North Dakota plains," *ibid.*, Vol. 48, 1920, pp. 82–83.

[15] Coe, A. B.: "How the chinook came in 1896," *Month. Wea. Rev.*, Vol. 24, 1896, p. 413.

Another account, by a former student,[16] is as follows:

One need only stay for a short time in the Missouri Valley region of Montana to see the effects of the chinook—popularly called here "the Montana monsoon." At Great Falls the winds were preceded by three or four days of clear, cold weather, with the temperature ranging from zero to — 20°. A general rise in temperature began with a slight wind from the southwest. Each day the winds grew stronger and the temperature rose. On the third day after the winds were observed I noted a temperature of about 40° for the whole of one day. I drove 24 miles one day across perfectly level bench land and it was remarkable with what steadiness the wind blew—not a gust or flurry was felt.

Again, from another correspondent in Montana (dated Butte, December 10, 1910):

Here is something that actually happened one day when I was in Great Falls two years ago. There had been a cold spell for over a week; the temperature had fallen to more than — 30°, and averaged — 20° for the week. I shall never forget that cold week. We used to sit on the radiator in the office all day to try to keep warm, and when we got away from the radiator we were cold again in a few minutes. This particular day at about quarter past seven, when I went to breakfast, it was about — 20°, and about 2 P. M. the temperature was well above 32°. The main street in Great Falls was water all over, where previously there had been several inches of snow This chinook lasted three or four days, and it was nearly like summer while it lasted. A chinook will last from a few hours to a few days. It blows from the southwest, and is not only warm but also very effective in melting the snow.

General Characteristics of Chinook Winds

The chinook wind is a characteristic feature of the eastern slope of the Rocky Mountains in Montana and Wyoming and as far south as Colorado. It is also noted, but has not been as well studied, elsewhere in the northern mountain regions of the Northwest, as in the Black Hills of South Dakota, in eastern Washington and Oregon, in northern Idaho and in other places. Occasional rather doubtful occurrences have been reported even farther east, quite well out on the northern plains. As fuller meteorological observations become available for this area, many occurrences of this wind, not heretofore discussed, will come to light. The late Professor Cleveland Abbe pointed out that a chinook-like wind also appears along the eastern base of the Appalachians.

The chinook is a warm and dry wind, similar in all respects to the Swiss *foehn*. Its direction along the eastern Rocky Mountain slope is in general southwest, *i.e.*, it blows from the mountains out onto the plains, but its direction is determined by the topography. It begins at any hour, day or night. In velocity it varies from a gentle breeze to a gale. It may blow steadily for many hours, or come in shorter spells interrupted by much colder and calmer inter-

[16] Thompson, Henry S., dated Butte, Montana, Dec. 23, 1905; unpublished.

vals. It may last three or four days. It usually begins as a succession of light breezes. Extraordinary stories are told regarding the warmth of the chinook, and this feature is abundantly established by reliable instrumental records. Coming after a spell of intense cold, it is often described as soft and balmy "like a summer zephyr." The preceding temperature may be 20° or 30° below zero and the rise frequently amounts to 20° to 40° in fifteen minutes Professor Abbe reported a case at Havre, Montana, March 7–8, 1900, in which the thermometer rose suddenly, shortly after midnight on March 7, from 11° to 42° in three minutes. After remaining nearly stationary for several hours, the temperature fell from 44° to 18° in three minutes, and in 20 minutes more, it fell to 11°. Between about 5 and 6 A. M. on March 8, it rose from 20° to 40.° After a few hours it began to fall rapidly again, and in an hour and a half dropped from 43° to 9°.[17] These rapid fluctuations are due to the alternation between the warm chinook and the general conditions of cold which assert themselves as soon as the chinook ceases to blow. There is a surging back and forth of the cold air which normally covers the lowlands in winter, and which is temporarily displaced by the warm air of the chinook. Many other instances of remarkable temperature changes might be cited. Occasionally changes of nearly 100° take place within a few days. A rise of as much as 40° in 15 minutes is, however, rarely attained. The maxima during chinook winds are seldom over 40°, but a rise from below zero to 40° or 45° in a few hours is clearly a very marked phenomenon, and one which inevitably has important economic and physiological effects. Isolated areas of relatively high temperature may thus be produced where chinook winds are blowing along the eastern base of the Rocky Mountains, and these "islands" of warmth occasionally appear on the regular daily weather maps if the warm winds happened to be blowing at the time of the regular 8 A. M. (Eastern Standard Time) observations on which the weather map is based.

The sky is usually fair or clear over the plains during a chinook, but over the mountains down from which the wind blows, dark "chinook clouds" are seen, and at the summits and on the farther slopes rain or snow may be falling. Burrows has pointed out that the chinook does not always follow the mountain slopes closely as it descends, but may be blowing on the upper slopes, passing aloft across a belt at the base, and then appear again at the surface at some distance—100 or more miles—from the foot. Under such con-

[17] Cleveland, Abbe: "Sudden temperature changes in Montana," *Month. Wea. Rev.*, Vol. 28, 1900, p. 115.

ditions, there is a belt of very low temperatures along the base of the mountains, with moderate temperatures higher up on the slopes and out on the plains. Travelers crossing the Rocky Mountains in Montana in winter often meet this phenomenon. The case is cited of an east-bound passenger train on the Northern Pacific Railroad which left the summit of the pass with mild weather and temperatures above freezing, and in half an hour had descended into a district where the temperature was — 13°.

Origin and use of the name "Chinook"

It appears that the term chinook as applied to a wind was first used in western Oregon and Washington, and also in British Columbia, to designate a warm, moist southwesterly wind coming from the general direction of the district formerly inhabited by the Chinook Indians on the lower Columbia River. It was, perhaps, quite independently of this particular use of the term, applied by early settlers along the eastern base of the Rocky Mountains to the warm dry wind descending the eastern slopes of these mountains, which was then, and unfortunately still is, thought by many persons to owe its high temperature to the warm waters of the Pacific Ocean. The name is often applied at the present time to the warm, damp southwesterly winds on the coasts of Washington and Oregon, but its use should be limited to the warm and dry descending winds, of distinct *foehn* type.

Weather Map Types Favorable for the Occurrence of Chinook Winds

The general pressure distribution favorable for chinook winds along the eastern base of the Rocky Mountains in Montana and adjacent districts is a high over the central Plateau and a low moving eastward from British Columbia to Manitoba, and appearing on the United States weather map to the north of the northern plains. Such a condition results in a general flow of air from the southwest, across the mountains, and then down onto the lowlands to the east, the steepness of the barometric gradient determining the velocity of the wind. Chinook winds may blow at any time of the year, but they are most common in winter because the pressure distribution is then most likely to be favorable and because the temperature changes are then most marked and noticeable. A fairly persistent anticyclone (continental high) is a characteristic of the Great Basin region much of the time during the winter months, with cold weather. When, at the same time, the pressure is low on the eastern slope, conditions are favorable for the blowing of chinook winds and hence for mild weather, in the latter region. Chinooks will

occur on the western slopes of the mountains whenever the gradients are such as to cause a flow of air across the ranges to the west, but up to the present time they have received far less attention than has been the case with those on the eastern slopes, where they are more common because most of the cyclonic storms pass eastward along the northern boundary from the Alberta district. The reason that these winds do not occur farther to the southward is to be found partly in the difference in the cyclonic and anticyclonic controls, and partly in the more uniform temperature distribution in lower latitudes. They have been described as far south as southern Colorado, where they occur when a low pressure area or trough extends farther south than usual along the eastern base of the Rocky Mountains.

Origin of the Warmth and Dryness of the Chinook Wind

There is no mystery about the high temperature and the low relative humidity of the chinook. The explanation given forty years ago by Hann of the Swiss foehn applies equally well to the American chinook. There is no importation of warmth from the Pacific, any more than there is an importation of high temperatures by the Swiss foehn from the Sahara, as was once supposed. Under the prevailing pressure distribution, the air of the chinook is forced to descend rapidly from the mountain tops to the lowlands. In doing so, it is warmed dynamically and its capacity for water vapor increases, so that it becomes relatively drier. Free air observations have shown that the temperature aloft is even higher than that at the surface.

Economic Aspects of Chinook Winds

During the colder months, chinook winds are important factors in the local climates of the northwestern mountain states They temper the severity of the winters, bringing welcome relief from the extreme cold and, when they occur often, distinctly raising the mean monthly and annual temperatures. The most marked temperature changes which take place during the winters of western Montana are due to chinook winds following severe cold. But it is their extraordinary effect in melting and evaporating the snow which has attracted the most attention. It is impossible to overestimate their economic importance to the cattle interests, as is pointed out in the graphic description of a chinook quoted at the beginning of this section. The coming of a chinook at a critical period saves thousands of cattle from starvation and freezing. The warmth melts the snow, as one correspondent expresses it, "just as though hot water or steam were directed against it." Because of

this wind, stockmen can get through the winter with much less stacked hay than would otherwise be required. Domestic and other animals exposed to the severe winter weather outdoors without shelter are not only able to secure food because of the chinook, but find in its warmth a welcome relief in their hard fight against the cold.

Evaporation and melting are so rapid that a foot of snow may disappear within a few hours, being "sucked up from the ground" without even a trickle of water, as one description has it.[18] At Helena, Montana, a snow-cover 10 inches in depth has disappeared over night, leaving a dry surface the next morning. In mid-winter as much snow will disappear during a few hours of mild and balmy chinook weather as would melt in the same number of days of the usual spring thaw. Chinooks aid greatly in keeping the railroads free from snow-blockades and, by favoring a melting and then a freezing of the snow in the mountains, they store up water in the form of ice for summer irrigation. The chinook, to quote Burrows,[19] "is an ever-welcome guest, whose coming is indicative of good, and whose absence would be a momentous evil." There are, on the other hand, a few drawbacks. In the case of many persons the warm dry wind has unpleasantly stimulating effects on the nerves, and because of the dryness, chinook weather is considered especially dangerous by the fire patrols in the national forests.

Winds of Chinook Character in California: "Northers" and "Santa Ana"[20]

A marked climatic characteristic of the Valley of California is an occasional strong northerly wind which, during the warmer months of late spring, summer and early autumn, has desiccating qualities which cause it to be much dreaded by farmers and fruit-growers. This "norther" derives its drying power from the fact that it has been dynamically warmed by compression during its descent from the Siskiyou Mountains to the north. In other words

[18] *Month. Wea. Rev.*, Vol. 35, 1907, p. 176.

[19] Burrows, A. T., *loc. cit.*, p. 136.

[20] See "Meteorology in California," *Amer. Met. Journ.*, Vol. 3, 1886–87, pp. 206–209; Campbell, Archibald: "Sonora storms and Sonora clouds of California," *Month. Wea. Rev.*, Vol. 34, 1906, pp. 464–465; Blair, Thomas A.: "Northers of the Sacramento Valley," *ibid.*, Vol. 37, 1909, pp. 132–133; Carpenter, F. A., and Garthwaite, J. W.: "Memorandum on air drainage in the vicinity of the Corona district, Cal.," *ibid.*, Vol. 42, 1914, pp. 572–573 (gives photographs of a norther dust cloud, and of a hygrograph record during a norther; also weather map showing pressure distribution favorable for northers in southern California).

it is of chinook nature. It blows when the pressure is highest to the north, and usually lasts from one to three or four days. During the summer months this norther is very hot as well as dry. It often seriously injures vegetation, drying fruit and scorching and killing young leaves. The soil dries up and cracks. Human beings suffer from nervousness and headaches, and become irritable and impatient. It is said that in the early days in California, if a murder or any personal violence resulted from a quarrel which occurred during a norther, that fact was taken into account as an extenuating circumstance. During a norther, cattle are restless and cows are reported to give less milk than usual.

In southern California, in the vicinity of Los Angeles, the "norther," under topographical control, may blow from northeast or from other directions. It is locally known as the Santa Ana because of its association with the pass and river valley of that name. In San Diego County the hot dry wind comes from the east. If such a wind blows at a critical time in the life of the fruit trees, in spring, it may do considerable damage.

Carpenter and Garthwaite have published an excellent photograph of the dust cloud preceding a norther in the Los Angeles district.[21] With increasing velocity of the wind, this cloud becomes thicker and more extended, and finally obscures everything. At Claremont, Pomona County, California, at 4 P. M., March 18, 1914, the relative humidity during a norther was recorded on the hygrograph as 5 per cent. with a possible error of 4–6 per cent. In four hours it rose to 97 per cent. with the cessation of norther conditions.

[21] Carpenter, F. A., and Garthwaite, J. W.: *loc. cit.* Fig. 3.

NEW VISTAS OF ATOMIC STRUCTURE

By HARVEY BRACE LEMON
UNIVERSITY OF CHICAGO

If, O gentle reader, you are by vocation or avocation scientific, and of that type of mind which believes imagination should not be given rein save in the formation of scientific hypotheses; if you hold the powers of ten vastly more informing towards infinity than any other kind of human language—be constrained not to peruse these pages. This exposition is designed rather for those in modern business and professional life in whom the spark of romance yet lives and who would still keep acquaintance with the gods of Olympus.

These indeed are days when one can know but little of the world save in the limited field of his own pursuits. So highly specialized have our professions become that many of us are living in a different age, and a world apart from our fellows. We can not read the language of their textbooks and technical publications —nor can they read ours. Under such conditions we can maintain the peerless treasure of an open mind only by continually cultivating contacts, superficial at best, with the realms of others' thoughts and lives.

If you could but hear this story from the lips of one, who, burning with the self-kindled flame of genius, has traced his meteoric trail through the vast dark region of atomic cosmogony, you might indeed be held enthralled by the recital. Such men, however, follow lonely lives and lofty thoughts in silence. They seldom speak in periods attuned to mankind's common ear. If now and then some one among them of less solitary temperament can pause, and, like Antaeus of old, touching mother earth, voice those thoughts that all ages and races of men have understood, then alone can others be brought into that palace of dreams where we abide.

The average physicist, especially if endowed with the rather practical bent of the engineer, occupies most of his time in the basement, between the floors and in the wall spaces, with the plumbing of our civilization. Sometimes he digs deep into the earth for contact with the sources of supply. Sometimes also he ascends to the roof and makes an opening that looks towards the sky and sees the stars, but excursions like these are usually taken only by the master artisans of the craft, by Kelvins, Rayleighs, Michelsons or Ruther-

fords. Fortunately, indeed, for all the rest, every hole that is made by them remains and the humblest apprentice may look through it forever after.

Our life, however, is spent for the most part, not star gazing, but with tools and torches—with cement and solder. Our imaginations are well disciplined, and our facility in argument acquires much inertia, because our laboratories are dedicated to the discovery of facts, and not to the discussion of opinions, and because these facts do not appear except as the result of much tabulating of numbers and of long and arduous calculations. This veil of mathematical complexity constitutes a nebulous fog through which vision for the majority is entirely obscured. Even the most experienced are led astray at times by the warped perspectives and the misty exaggerations of such a medium, and to no one time or generation has it yet been given to view the whole. Ours are disappointments that come to the traveler whose journey through a beautiful mountain region is limited to a few days, and who encounters a spell of rainy and foggy weather for that time. Our imaginations have anticipated the vista, the immediate foreground suggests it, and we glimpse it through a momentary lifting of the veil, but our time of departure from the scene approaches and the clear view is still withheld. Under such circumstances the real woodsman then finds contentment in the little clearing around his fire. This region is replete with beauty and interest. Mushrooms, ant lions, arbutus and mosses, tiny complexities of plant and animal life can fill a recreation period with quite as much interest as mesas and monadnocks, distant ranges and valley vistas.

With his mechanic's tools, however, the physicist has achieved results of great significance in our social structure. He, primarily, is to be held responsible for the deadly efficiency and the killing pace of modern life and all of the ills that these things bring in their train. With radio and long distance telephone ever reaching out their tentacles, the business man can no longer remain on this planet and escape the activities of commerce. If high-powered cars and concrete highways, airplane post and passenger service in a pinch may enable him to crowd a week's activities into a day, so that all his time for meditation and reflection has disappeared, he may thank us. Because we are able to double plant production and treble dividends our star just now is in the ascendant, but it is not so generally appreciated, however, that we have at the same time made it highly probable that if another world war should arise, the struggling governments will be able with either a handful of devoted men or by purely mechanical means to annihilate at a stroke large portions of each other's centers of population, men,

women and children without distinction. Society, still medieval in its ethical and political evolution, is in possession of weapons and forces, forged by us, that hang suspended over it, like the sword of Damocles, by the threads of our frail statesmanship, political ignorance and incompetence and public and private greedy enterprise.

What a marked contrast between this outlook and the beauty of nature's pageant, as it is being unveiled in the realms of the inorganic! Here we find perfection—finished, flawless, final. Our spirits buffeted and baffled in the eager restless strife of living—in the passionate, pitiful activities of mankind—here find themselves transported to a world of things impersonal and dispassionate, to an era far removed from the travail of evolution, into an element where storms and tempests are unknown Chance, the blind goddess, rules here. Probability, whose myriad forms alone are equal to the reckoning, is all in all. She is not, here among her own, the captious creature that we recognize mixing up the affairs of men, marshalling vigitillions to our units, so vast her sway that error is no more For eons that are past, and eons that are to come her laws are followed true, no variation, no exception, no omission, no mistake. With vastly greater differences among her subject atoms than exist among the races of mankind, her laws suit all alike. Little credit have we of the twentieth century for the recognition of this divinity!

It was Democritus of Abdera (460 B. C.) who first saw in the disappearance of water from a crock as it evaporated a manifestation of the atomicity of things. Recognizing as equally unthinkable the infinitely divisible or the finitely indivisible, Democritus made the more practical choice of the latter as a hypothesis and called the finitely indivisible *a-tomic.* Two thousand years before Lavoisier, he preached the indestructibility of matter. He left no school of disciples, none but Empedocles amplified his physics and chemistry, and when twenty centuries later Boyle, Rumford, Joule and Clausius turned again to think about physical problems, it was to begin where Democritus left off.[1]

What, then, has modern thought done by way of adding to the Atomic Theory of Democritus? First, these atoms have been endowed with motion, and very recently have been subdivided.

The first contribution can be regarded merely as an amplification of the ideas of Democritus—indeed, he must have thought about it. Rumford and Joule were faced with the necessity of accounting for the constant amounts of heat that appeared as the invariant result, when the same quantity of mechanical work was

[1] *Cf.* Carl Snyder, "The World Machine," for an interesting discussion of Democritus from which we have rather freely quoted.

expended, and seized upon molecular motion as a hypothesis; mechanical energy on a molar scale being transformed to the same identical kind of mechanical energy but on an atomic or molecular scale. Joule[2] also saw that the picture of a confined body of gas consisting of myriads of elastic points flying at random, each having a minute mass, and because of its velocity a minute momentum, would supply a simple mechanism for the observed laws of gases. The pressure imparted to the walls of the containing vessel would simply be the integrated momentum shocks of all these particles as they rebounded from collision with the walls. Heating the gas, if interpreted as raising the molecular velocity, would increase the pressure as demanded by the experimental fact. Compressing the gas by crowding more molecules into the same space would increase the number of impacts and raise the pressure in the direct ratio that experience had shown was the case.

Now, if an hypothesis fits and supplies an explanation of the group of facts for which it was designed, this indicates discrimination on the part of those who formulated it, rather than that the hypothesis contains any intrinsic content of abstract truth. As is usually the case, more careful experiments in this field showed that the facts for which the kinetic hypothesis was designed were not exactly correct Quantitative work did not bear out the original computations Here we find the acid test of any hypothesis. Must we now discard it altogether and build anew, or will careful scrutiny show that it may be amplified somewhat or applied a little differently? Joule had for the sake of simplicity of computation (to a physicist a most valid excuse) taken mathematical points for his molecules—making the leap of infinite divisibility unthinkable to Democritus. Clausius now took the same picture, but, postulating the natural assumption that the molecules must themselves occupy space and that each must exclude at all times all others from itself, he showed that this more sensible point of view when investigated numerically would lead one to expect exactly that departure from the simple relation of the gas laws that careful work had shown to exist. For exactness, we must add that the existence of attractional forces between these molecules had also to be included to give the result indicated. But this, too, was a very sensible, indeed almost inevitable, assumption, since we knew that mass in the gross attracts all other mass, and in the minute coheres together with great tenacity.

Furthermore, when a physical fact can be expressed in algebraic form, a purely mathematical operation on that equation may result in its being transformed into another equation which may in turn

[2] Bernouli is credited by some with having anticipated Joule.

have an interpretation sought in physical phenomena. Such phenomena may have been hitherto quite unsuspected. We are led to them not by direct contact with nature, but by the mysterious rites of symbolism, which here contain, however, nothing more deadly than logic If, in the spot where the symbols say the treasure lies, we delve, and find not only treasure (for treasure lies wherever one digs), but those specific articles of value that the formula foretold —our hypothesis, glorified into something that is more than merely the creation of our minds, lives transcendently, outlasting the mind that fathered it and perhaps the age and race of men that knew its birth. It is the expression of one of those immutabilities of the universe that have existed and will exist forever.

Thus, from the parenthood of atomic ideas, the kinetic theory of heat born in 1840 has now found its place in the sun. Yet up to 1914, such is the temper of the scientific mind, one of our most illustrious chemists, Wilhelm Ostwald, was still skeptical, preferring to think of energy rather than matter as atomic. In the new edition of his "Outline of Chemistry," however, we read:

> I am convinced that we have now become possessed of experimental evidence of the discrete or grained nature of matter for which the atomic hypothesis sought in vain for hundreds and thousands of years . . . The atomic hypothesis is thus raised to the position of scientifically well-founded theory.

In other fields of scientific endeavor one can observe quite parallel cases. The Copernican theory of the solar system that makes the sun and not the earth the center, and the Pasteur theory that many diseases are caused by micro-organisms and may be combated better by the destruction of the cause than by prayers to the saints, also rest scientifically on the same kind of evidence They have struggled up to the light against the same type of opposition, and are now to be considered as imperishable monuments of this last great scientific era.

The second addition that has been made to the ideas of Democritus has come but very recently. Its shadow, however, like that of all great things, preceded it afar. Eighty-eight years ago, to the eternal glory of England, Michael Faraday discovered that if equal quantities of electricity were passed through a conducting solution there would be deposited out weights of material that were strictly proportional to the relative weights of the atoms involved. Thus, he identified with each atom a definite quantity of electricity, and this quantity was the same for all atoms of the same chemical nature Atoms of different chemical nature or valence had associated with them two or three or some other small and exactly integral number times this fundamental quantity.

The charge associated with each chemical atom in solution was later discovered to exist in gases under special conditions It was but twenty years ago in the *Philosophical Magazine* for March, 1902, that Kelvin, under the whimsical title "Aepinus Atomized," said: "My suggestion is that the Aepinus (electric) fluid consists of exceedingly minute, equal and similar atoms, . . . much smaller than atoms of ponderable matter." This electric atom and every integral multiple of it up to about two hundred, has been isolated and counted not once, but many thousands of times during the last ten years by Wilson, Millikan and others. These experiments which establish the atomic nature of electricity are mentioned by Ostwald in the quotation abridged above as having convinced him finally of the atomic nature of matter itself. Indeed, they are utterly inexplicable on any other hypothesis.

Thomas A. Edison, during the early stages of the development of the incandescent lamp, observed mysterious currents that passed through the highest possible vacuum from a glowing filament. These currents could not be attributed to the presence of charged atoms in a region from which the atoms had been almost completely removed. Through the work of Lenard, Crookes, Lodge and especially J. J. Thomson, these currents have been found to consist of tiny electric atoms shot out from the matter in which they normally reside and traveling with velocities of from ten to one hundred thousand miles per second. These electric atoms, called "electrons" first by Johnstone Stoney, possess other properties in keeping with their prodigious speed of emission. They are capable of deflection in a magnetic field and this deflection shows not only that the charge they carry is negative (*i.e*, similar to that obtained on sealing wax when rubbed with fur), but also enables us to measure the ratio of the charge to the mass, e/m. Knowing the charge carried by the individual electron from independent experiments, we can thus divide out and obtain the mass. This mass we are familiar with as being 1/1845 part of the mass of the lightest known atom, hydrogen.

Of very great significance also is the fact that whatever may be their source—whether they are released by light action from the surface of zinc or of potassium or many other metals (the so-called photoelectric effect), or liberated by high temperature from wires of tungsten, platinum or filaments of carbon (the Edison effect) or shot out at much higher velocities of over 180,000 miles a second during the spontaneous disintegration of a radioactive element, which itself may be either a heavy metal, an active alkali or an inert gas—these electrons are in all respects absolutely alike. It would appear then that we have here a common material from

which the 92 different varieties of matter we call the elements are built.

By years of patient study, weighing, combining, substituting one substance for another, re-weighing and weighing again, the chemist has taken the almost infinite number of different things on and in the soil of our earth and found them all to be combinations of less than one hundred different substances, the elements. The romance of the details of this story is enchanting but can not be touched on here. Pushing the field of exploration ever further the chemist ultimately found himself at every turn baffled by a fact undoubtable, inexplicable and vastly intriguing. There was a rhythm in these elements. If arranged in a row beginning with the lightest and proceeding to the heaviest, it was seen that at equal intervals along the line there were recurrent similarities between these fundamentally different things. Newlands, first, and Mendeléeff, finally, with the greatest completeness formulated these "octaves" in the periodic law. The recognition of this law caused rapid extension of exploration in chemistry, because its general character pointed out how and where to work. The explanation of the law remained for generations an utter mystery.

However, with the discovery of electric atoms of a more elementary nature than the elements, the clear light dawned for chemistry. We now recognize in the elements, as we progress from light to heavy, structures fundamentally electrical in character, as foreshadowed by Faraday, and built up from simple to complex by a process that we are soon apparently to understand.

And, as the spectroscope first showed to man that in all the starry sky those mighty suns were as ourselves composed of but stone and iron and hydrogen and oxygen and clay, that we in true chemical sense were fashioned as the image of the Almighty, so now in these same "cosmic crucibles," thus aptly named by Hale, do our spectroscopes read the appalling swing of inorganic evolution. Vast as was the time required for our race to emerge from the slime of the Proterozoic seas, this interval is but one stroke of that cosmic clock that measures the birth in a star, first of hydrogen and helium, and then little by little as the cycle goes, the further cementation of the building material into lithium, boron, carbon, oxygen and iron, and, later still, the union of these and others into oxides, compounds, rock and stone. Irresistible is the suggestion that life itself must also be there somewhere between the stages of incandescence and eternal cold. Thus, in the pageantry of the sky we are permitted to glimpse into the eternity of future and of past, and see the two unite as they vanish.

Matter then contains and essentially consists of atomic structures, each an aggregate of more minute atoms whose nature is that

of negative electrification. Is this all? If so, you may be formulating the question, How, then, are these electron systems to be held together? Electrification, we have always been told, repels other electrification of like kind. Is our hypothesis going to remain forever at variance with this elementary and obvious fact? For quite a long time indeed we have been baffled by this very question. Our hypothesis has appeared hopelessly hemmed in from the light by this very wall. The early postulates of Thomson of uniform spheres of positive electrification, through which the electrons swim, were admittedly guesses for the sake of simplifying computations. The breach has now been made, however, by Rutherford and his brilliant associates. Through it the light comes streaming, and every number of our journals is replete with new material confirmatory of the general features of our point of view, and supplying many new hitherto unsuspected details that may be fraught with great importance ultimately to all mankind

One of the radiations given off by radium and many other radioactive substances has long been known to consist of particles charged two units positively and having a velocity of about 18,000 miles per second. These alpha particles, as they are called, are over 7000 times as heavy as the electron, and yet can plow through hundreds of thousands of other atoms and create no disturbance. They will come through a glass wall for years at a time and leave no holes. They must be accordingly inconceivably minute compared with the atoms themselves, or else the structure of the atoms must be such that they are penetrable, as is the solar system by an occasional comet. On exceedingly rare occasions, however, we observe an alpha particle completely fail to get through another atom, and a little oftener we see it swung out of its straight line of flight by such an encounter. The dynamics and geometry are simple, and compel the conclusion that a positive nucleus exists at the center of all atoms, minute beyond conception, but charged and massive. This positive nucleus established by direct experiment is the dominating sun, as it were, of this tiny planetary system. With it must be associated practically all of the system's mass—the planetary electrons contributing but very little. Here, as in exterior cosmogony, we find the inverse square law of Newton still dominant. Other great names recur. A Darwin has shown that the inverse square law of repulsion is the *only* law compatible with Rutherford's experiments. Furthermore, the central forces in this nucleus are proportional to half the atomic weight which is, as a matter of fact, the number that represents the position of any element as it stands in rank and file in the chemical table. Hydrogen, the first, occupies a unique position; helium, the second, weighs

four; lithium, third, weighs six plus; beryllium, fourth, weighs eight plus; boron, fifth, weighs ten plus; carbon, sixth, weighs twelve, exactly; nitrogen, seventh, weighs fourteen, to one part in 1500. The atomic ordinal number, then, is about half the atomic weight. It is regarded nowadays as of much greater significance than the atomic weight itself.

From an altogether different angle we have recently found a method of attack. Equipped with diffraction gratings by Rowland and by Michelson, the spectroscope has revealed to us not only the chemical composition and physical conditions of the stars, but their velocities and sizes as well. Thus are we able to formulate the fascinating story of stellar evolution. Similarly adaptable in the microcosmos, the spectroscope in its early form has given quite independent testimony not only of the kinetic dance of molecules and atoms, but very definite hints as to the nature of the electric mechanism which constitutes their essence. To Laue of Munich the idea first came that in a crystal nature had supplied us with a grating a thousand times more fine than Michelson could ever hope to rule, and endowed it with the perfection that nature produces as a matter of course and man strives in vain to imitate. The crystal spectrograph extended our vision by revealing the true nature of the X-Ray as light of extremely short wave length.

During the early years of the war, there was at the Dardanelles, among those boys who met death with laughter on their lips, a British soldier by the name of Moseley. His brain, pierced by a Turkish bullet, had made contributions to our knowledge of X-Rays, which, aside from his valor, will ever rank him among immortals. These contributions are as far removed from the shadowgraphs of Roentgen as the measure of a giant sun by a Michelson interferometer is from silhouettes traced by shadows on a screen. Moseley discovered that there is revealed a relation of utmost simplicity between the wave lengths of corresponding lines in the X-Ray spectra of different elements and the atomic numbers of these elements. Even the constant that the formula contained, Bohr has shown to be not empirical but demanded by the superposition of the fields of the nucleus and those of the planetary electrons. Thus the ballistics of Rutherford's projectiles are given quantitative verification by the optics of Moseley.

J. J. Thomson first pointed out how altogether clumsy were the most refined methods of the chemist in the matter of determining atomic weights which appeared in many cases to be hopelessly at variance with these more recent contributions. Refining the methods of Goldstein, whose mysterious "canal rays" turned out to be nothing more recondite than streams of flying atoms, Thomson now

weighs the atoms directly by hurling them with prodigious velocity through electric and magnetic fields and measuring by photography how they swerve from the rectilinear. The most important result so far of the positive ray work of Thomson has been the discovery of the isotopes, which has laid forever the ghost of atomic weight discordancies.

There exists in our atmosphere, discovered by Ramsay, a rare gas comprising but 1½ parts in a hundred thousand of the total. It is inert, enters into no combination with any other substance, and was called by its discoverer "Neon." Neon's atomic position of ten demanded twenty for its atomic weight. Chemical methods showed indubitably that it weighed 20.2 and the 1 per cent. error has remained intolerable. Thomson has discovered that there are two neons, one weighing exactly twenty and the other exactly twenty-two. The latter is very much less abundant than the former but is inextricably mixed with it, and the measured weight has only the significance of an average value.

Since neither of the forms of neon possess any chemical affinities, it might at first sight appear as if the difficulties of the usual chemical methods for separating them were here exceptionally great. However, when this positive ray method was applied by Aston, and more recently by Dempster, to other elements whose weights were obviously discordant, there have been found two kinds of lithium, weighing exactly six and exactly seven, two kinds of boron, ten and eleven; three kinds of magnesium, 24, 25 and 26; four kinds of zinc, 64, 66, 68 and 70; and no less than six kinds of mercury, ranging from exactly 197 to 204. These different varieties of an element, or isotopes, differ in weight alone. Their other physical and chemical properties are identical. However, substances of different mass diffuse at different rates and partial separations of the isotopes of mercury and of chlorine have been made in sufficient quantity by Harkins to amply confirm these most sensational results. Why sensational? Because, if all the atoms are found to have simply related integral weights we have in this fact a necessary and sufficient argument to suggest a simple structure in that part of the atom with which the weight is associated, namely, the nucleus. Thus the atom is composed not only of electrons added one by one about its central nucleus, but this nucleus itself is a structure built more compactly but in accordance with a plan definitely related to the exterior and of the same essential entities.

Prout, as long ago as 1815, formulated the doctrine that all atoms were constructed of hydrogen, but this was little more than speculation suggested by the approximately integral character of the atomic weights. The scientist of the nineteenth and twentieth

century is not of the temper to dignify speculations that will not bear quantitative investigation. Here, however, is something strongly suggestive of what Prout had in mind, but formulated against a vastly richer background. Moreover, the doctrine of nuclear structure is not now without additional experimental proof.

Transmutation, the age-old dream of the alchemist, has ever been a fascinating vision. With the discovery of radioactivity and the chemical and physical untangling of this most puzzling field, we learned that transmutation was indeed no dream but an actual reality. However, there appeared to be a sacred inviolability about the process which not only kept it hidden from all save the most discerning eye, but also showed it to be something which the hand of man could not control. All the power of a harnessed Niagara could not alter, accelerate or retard it. Subatomic forces and energy herein revealed were as far removed, it seemed, from human contact as a distant nebula To look and to marvel was permitted, but not to tamper. Rutherford, however, in his Bakerian lecture at the close of 1920 announced that by directing alpha particles from radioactive Thorium C against nitrogen atoms, positively charged hydrogen atoms are released. These have greater energy than when released by similar experiments in hydrogen itself, and can not, therefore, come from hydrogen as impurity in nitrogen. Moreover, they possess mass for mass; energy greater by as much as 40 per cent. than that of the alpha particle that gave them birth. Likewise, from boron, fluorine, sodium, aluminium and phosphorus has this intrepid experimenter more recently obtained similar results. What is left of the element nitrogen after it has been so disintegrated has not yet been determined.

Now these positively charged hydrogen atoms really are the hydrogen nuclei themselves, since all evidence shows us that one electron is all that is ever associated with the neutral atom In these we recognize at last the electron's alter ego, and we have named it "proton." Charged positively by the same amount that the electron is charged negatively, the resemblance can not be carried further. One, 1,845 times more massive than the other, paradoxical as it appears, this strange couple, ill matched in everything except their perfect affinity for one another, are in all likelihood at the root of all matter.

Neutral hydrogen contains the simple pair, proton and electron, but such an atom is unsymmetric and does not exist, except transiently without uniting with another. The neutral molecule thus formed has its two electrons revolving in some manner, as yet unknown, about the line between its two nuclei. Helium has, within its nucleus, four protons closely associated with two electrons giv-

ing the necessary weight of 4 and residual charge of 2. Far outside the region of the nucleus are found the two external electrons. Here again the dynamics of the system is as yet but dimly seen. One or both of these electrons may easily be detached or disturbed. When so disturbed, the periods with which they vibrate are of enchanting beauty of color and possess an alluring simplicity of equation. Without its two electrons the helium nucleus is a marvelously stable system. This it is that we called first the alpha particle. Shot out from many radioactive explosions the stability of these helium nuclei is in no way affected even when they impinge on other atomic systems with sufficient energy to disrupt the latter. They are thought by some to constitute a secondary building unit. If this be true, all multiples of weights of 4 in the table should be singularly stable. No. 8 exists; but 12, carbon, 16, oxygen; 20, neon; 24, magnesium; and 28, silicon, are the only elements which have so far withstood Rutherford's attempts at disintegration. Similarly, if we do succeed in disintegrating these or any other elements, we should expect to get out of them helium nuclei in no inconsiderable amounts.

The recently much discussed experiments of Wendt, in which helium was thought to be found as the result of high temperature explosions of tungsten, are to be mentioned in this connection, although of too preliminary character to be yet recorded as a positive result.

Finally, let us offer a few crude illustrations of the scale of these things as contrasted with our own stature. The various powers of ten, in terms of which physicists think in this connection, have been purposely omitted, since to the average man a million, 10^6, even in dollars, is but an idle dream.

The size of an atom, if inverted and expressed in dollars, would make a nice little nest egg for the establishing and running of a university. The size is a hundred millionth of a centimeter, 10^{-8}. This is utterly beyond the most powerful microscope of this or any other age to discover, since our seeing is conditioned ultimately, not by our instruments, but by the size of light itself. With a good car, and a concrete road all the way, by driving an average of 200 miles a day, steadily without holidays, one would arrive at the moon in three years and five months. Try to imagine a group of investigators from a race of supermen with stature such that while standing on the earth their heads would be on the moon! In other words, let their six feet of stature expand to a quarter of a million miles, and let their laboratory, their alpha particles, their hydrogen, helium and other materials be built on the same scale. If we were now admitted to this giant world, the smallest atoms would appear quite

conspicuous to us, being spheres of about four inches in diameter. They would consist of impenetrable regions from which we and all other atoms would be excluded by the presence of terrific repulsive forces. Involved in an impact, their inertia would still be only about that of a gram weight.

Within this four-inch sphere, what would we see? If it were hydrogen, there would be the proton nucleus and the electron—nothing else. The electron would hardly be called conspicuous. In spite of the prodigious magnification we would still need a good microscope to find it. Its diameter would be but a ten thousandth part of an inch. The nucleus we could never hope to find. Its diameter would be about one ten millionth of an inch, so much smaller than a light wave, that no image of it could be formed.[3] Thus it appears we have not magnified sufficiently.

Making the nucleus large enough to see, let us suppose it to be one inch in diameter. The attendant electron would be 85 feet in diameter and swing in an orbit 170 miles across. For perspective let us compare such a system with our solar system, and alter the scale by even a more prodigious ratio. If the electron were the size of our earth its orbit about the central nucleus would have to be almost ten times as large as that of the earth. It would swing out in the vicinity of Saturn, 800 million miles away. The nucleus would be utterly invisible until one got quite close to it, for its diameter would be but four miles even on this cosmic scale. A man in this proportion would more than bridge the entire known universe of stars. Thus one can see that even the heaviest atom with its central nuclear pack of protons and electrons, possibly as great as one thousand miles in diameter, is for the most part empty space. Relatively great forces pervade this space. But other systems, if endowed with sufficient energy to overcome the existing repulsions, can pass right through and in general produce no disturbance.

External space is not nearly so filled with solar systems as internal space is with atoms. A beam of light will traverse our solar system in three quarters of an hour, but three and a half years is required for it to reach our nearest neighbor star. In the realm of atoms, however, the average separation of the systems in a gas like hydrogen at atmospheric pressure is only about 500 times their own diameters. If the stars were as dense, we would encounter one about every twenty days if we traveled on a beam of light. In

[3] The size of the proton (hydrogen nucleus) is quite problematical as yet. If its mass is due to charge distributed over a spherical surface in accordance to ordinary laws it must be a thousand times smaller than the electron, *i.e.* about 10^{-15} cm. The text is in accord with this estimate.

The nuclear pack of heavier elements, composed as it is of electrons and protons, is thought to be of same order of size as electrons themselves.

liquids and solids the packing is closer, although the systems are not in contact, the separation being of the same order as their own size. The number of these little systems in a cubic inch of atmosphere is appalling, 10^{19}. If all the people of the United States should by agreement try to count this number, each individual counting five per second, throughout each 24 hours, it would take our population of a hundred million souls over a thousand years to complete the task.

These are stupendous facts. As facts alone, however, they do not possess their greatest interest. Their significance in relation to our social order is the vital question for thoughtful men and women. Scarcely 150 years have passed since Franklin with a kite drew electricity from a cloud. Harnessed now, this modern genie of the lamp has become a slave to do our bidding. Deeply from the cup of knowledge also has it given us to drink. Clear heads and sober minds are needed, as never before, to watch lest the genie prove an evil one providing us with weapons for our own destruction.

The dreams of Jules Verne, that fired the imagination of our boyhood, incredible as they then appeared, are to-day in many instances accomplished facts. And, while natural conservatism, bred of scientific training, decries the possibility of our ever being able to unlock in quantity the stores of atomic energy, infinitesimal portions of which have already been released, we know not what the future holds. In H. G. Wells we have a contemporary writer, undoubtedly as well informed of the scientific tendencies of his time as was Jules Verne. Can it be that in his writings, also, there runs a vein of prophecy (using "prophecy" only in the sense of extrapolation from the curve of human progress in the past, which would indicate its probable course in the years to come)? Certainly, one who has seen the dreams of Verne fulfilled can not but shudder at Wells's horrible pictures of future civilization, enmeshed and entangled in the harness that science even now is forging.

But, after all, the curve is ours to alter. No predestination impels us towards destruction. As individuals in social and political life, we must keep pace with science; and, taking warning from the fate of Moseley, prevent the repetition of another such orgy of destruction as that which recently was detonated by the monumental stupidity of our so-called civilization.

For the present let us hope that the peak rate of scientific progress has been passed—that education and the broadening sympathy that comes from true culture may grow apace—to the end that man may see, and, growing in wisdom, reverence the incomparable perfection, the radiant beauty, the undeviating rectitude and the eternal character of the universe in which he lives.

A FLIGHTLESS NEW ZEALAND BIRD

By Professor DAYTON STONER
THE STATE UNIVERSITY OF IOWA

Of the many peculiar and bizarre types of birds found in the world probably none is more unique or interesting than the apteryx or kiwi of which there are but five or six species, all confined to the Dominion of New Zealand.

About three or four hundred years ago a group of large flightless birds, some as much as ten to eleven feet high, roamed over the volcanic hills of this land. The aborigines of the country pursued these great moas, as they were called, destroying them for food and perhaps also making use of some other parts of the body. So persistently were these giant birds persecuted that to-day not one exists and we know of them only through legends and the remains that have been found. However, their miniatures, in certain respects, are represented in the present fauna of the islands by the vanishing kiwi.

Only a few of these birds are left in the hills and more or less inaccessible bush of North Island, South Island and Stewart Island. Of late an endeavor has been made to protect the species all over the dominion and efforts toward conservation are being effected. Some of the zoological parks are so fortunate as to possess a specimen or two, the individual described in this article being, at the present moment, a captive in the well-kept park at Wellington. It is an example of the North Island kiwi, *Apteryx mantelli*.

One morning, in company with the keeper and Mr. Harold Hamilton, of the Dominion Museum staff, I visited the portion of the park reserved for this curious bird. Along one side of the low shaded enclosure flowed a small creek; near the middle of the area was a heap of sticks and brush, but nowhere was the kiwi to be seen. Entering the wire-netted compound and kicking at the pile of sticks the rather bedraggled and forlorn appearing occupant was soon dislodged and with reluctant and awkward gait it made off toward a shady corner, where it remained for a time quite motionless and apparently dazed by the bright rays of the sun.

One is at once struck by the strange appearance of this tailless and all but wingless creature. It is about the size of a domestic fowl; it has a rounded and compact body; the neck is short, but the bill is long and slender; the legs are short and powerful. Add to

KIWI IN WELLINGTON ZOOLOGICAL PARK, WELLINGTON, NEW ZEALAND
(Photo by Dayton Stoner)

this the much reduced wing, totally useless as an organ of flight, and the body covering of long, "stringy," hair-like feathers of a brownish or grayish-brown cast and the appearance of this singular bird is rendered still more un-bird-like Indeed, the North Island kiwi can scarcely be considered beautiful

The kiwi may truthfully be said to have the longest "nose" of any known bird, for the slit-like ventrally placed nostrils are located near the *tip* of the six-inch, semi-cylindrical bill, a condition which prevails in no other bird Numerous stiff, bristle-like feathers cover the face and base of the bill

The lower leg is covered with irregular, horny scales, and the three long, strong front toes are furnished with heavy, sharply-pointed claws A small fist or hind toe is also present.

When handled, our zoological park kiwi showed resentment by hissing and kicking—not backward so much as forward—and with sufficient force to cut one's flesh deeply It offered no resistance with the formidable-looking bill.

Kiwis are hardy, nocturnal birds which hide in holes or dark places during the day and come out at night to feed mainly upon earthworms and also, to some extent, upon vegetable material.

Under natural conditions a hole in a bank or under the roots of a tree is chosen as a nesting site and, in a burrow, partly natural, partly excavated by the female, the one or perhaps two white eggs

are laid. In proportion to its size the kiwi lays the largest egg of any living bird, a female twenty-five inches in length producing an egg five inches long and three inches broad. The birds will breed in captivity, the individual under discussion having laid eggs which, unfortunately, were destroyed before hatching by the flood waters of the adjacent stream.

Contrary to the general rule among birds, the male incubates the eggs and after a period of about six weeks the helpless young are hatched. They acquire strength rapidly and in a few days are able to join the parents in searching for food.

A very well-executed habitat group, showing one egg, three young and four adults of the North Island kiwi, is exhibited in the Auckland Institute and Museum.

It is to be hoped that such satisfactory protective measures for the kiwi may be taken by the New Zealand government that it will be in no danger of the fate that has befallen its even more remarkable precursors, the moas.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

MOTION PICTURE OF ATOMIC COLLISIONS

Staging a collision between locomotives is an old movie stunt but Professor W. D. Harkins, of the University of Chicago, has gone to the opposite extreme in setting up a camera that will take pictures of the tracks of the atoms through space and their occasional collisions.

Since the atomic particle to be photographed is only about a million millionth of an inch in size and is moving at a speed of ten thousand miles a second, taking its picture is more of a feat than filming a slow-coach locomotive that may be making a mere sixty miles an hour. To work out a way to do it required an alliance of Anglo-Saxon and Japanese brains, the "Wilson-Shimizu apparatus," it is called. In this ingenious contrivance advantage is taken of the fact that when moist air is cooled suddenly the water is precipitated from the air in the form of dewdrops that deposit upon the walls of the vessel or upon any electrified particles, such as dust, that may be floating in the air.

Now the smallest of all possible electrical particles is that known as the electron, which is so minute that it would take 1,840 of them to weigh as much as the smallest atom, the atom of hydrogen. These electrons are more or less loosely attached to the atoms of all kinds of matter; so loosely in fact that you can rub some of them off a piece of glass with your handkerchief as is shown by the fact that you have "electrified" the glass.

We can get free electrons from air by knocking them off the atoms of nitrogen by bombarding them with what are known as "alpha particles." The alpha particles are the fragments of helium atoms thrown off when the metal radium decomposes. They carry a double charge of positive electricity and are projected from the exploding radium atom at a speed some twenty thousand times as fast as a rifle bullet. Their momentum is so great that they plunge right through the atoms they encounter and may travel several inches through the air before they are slowed down, leaving behind a trail of some 200,000 fragments of nitrogen atoms. These fragments being electrified may each form the center of a minute dewdrop. If now a bright light be thrown on the screen from the side, the track of the alpha particle will be seen as a shining line of illuminated drops, and may be photographed.

But once in a while the flying alpha will do more damage to an atom than carry off one of its outer electrons. It may chance to hit an atom in its central nucleus, where most of its mass is concentrated, and so smash it to pieces. Now the nucleus of a nitrogen atom is made up of hydrogen and helium and either of these may be dislodged. In Professor Harkins's snapshots we can see the result of such a collision. The alpha particle has bumped up against the nucleus of a nitrogen atom and bounded back, while the dislodged fragment of the nucleus is projected forward, so the track appears to fork.

SPENCER FULLERTON BAIRD
The distinguished naturalist, from 1850 to 1887 assistant secretary and secretary of the Smithsonian Institution, the centenary of whose birth has been celebrated this year

THE CHEMISTRY OF A SKYSCRAPER

The first thing that attracts the attention of the newcomer as he sails up New York Bay is the imposing group of tall buildings, unequalled elsewhere in the world. As he looks up at one of these strange structures he thinks of the architect who planned it and of the builder who constructed it.

But he does not think of the chemist who is behind them all and without whom it would be impossible to erect and equip a skyscraper. He made the ink and paper with which the architect drew his plans and he made most of the materials that the builders use. For even what seems to be natural material will be found on closer examination to have passed through the hands of the chemist. The doors and casements may be grained to look like wood but tap them and you find them steel. There may be a coating of natural stone on the side facing the street, but this is a mere concession to conventionality, for the building is mostly composed of cement, concrete, brick, mortar, plaster, terra cotta, tiles and glass, all of which are manufactured by chemical processes. The skeleton of the skyscraper is of steel, something not found in nature. The furnishings and electrical equipment are made largely of brass, bronze, tin, aluminum, rubber, celluloid and the like, all chemical products. So are all the paints and enamels that adorn and preserve the walls and metal work.

In the skyscraper work goes on by night as well as by day, for rooms are lighted by electric currents flowing through wires of a new metal, tungsten, enclosed in glass bulbs from which the air has been exhausted and perhaps replaced by some inert gas. The chemist not only provides for fire in the form of matches, but he also furnishes the means of putting out fire if it gets out of bounds. In the halls you will see a fire-extinguisher ready, at the turning of a tap, to throw out a stream of water and quenching gases.

If you look into a shop window on the lower floor you will see gay garments, colored with dyes prepared from coal-tar and in many cases made from artificial fiber that rivals silk in sheen and beauty. In the corner drug-store many of the medicines are also prepared from this same coal-tar which once was thrown away or burned up as good for nothing. The chemist provides the weapons with which the doctor wards off the attack of microscopic enemies of mankind, the microbes.

The roots of the skyscraper go down deep in the ground and are embedded in the solid rock. But it would not have been possible for the building to have been dug so deep if the chemist had not provided explosives. The nitrogen gas which he extracted from the air and fixed in the form of dynamite or gunpowder returns to freedom with such violence as to rend the rocks.

In the top-story of the skyscraper there is probably a restaurant, to take advantage of the lofty view, and there, too, the chemist plays an essential part. Cooking is a chemical process and so also is cooling, which is almost as important to the modern chef. The foreign fruits and perishable meats have been preserved by artificial refrigeration by means of ammonia made from the nitrogen of the air. The china, the glass, the cutlery and the kitchen utensils are all chemical manufactures. The vegetables are grown by the aid of chemical fertilizers, containing potassium, phosphorus, nitrogen and lime. The foods and drinks are analyzed in the market so as to see that they contain no dangerous impurities or adulterants. The water supply of a great city has to be watched from day to

Joseph LeConte	F. W. Putnam	H. L. Fairchild
President	*Permanent Secretary*	*Local Secretary*

Officers of the American Association for the Advancement of Science, Rochester Meeting, August, 1892

day lest it should be visited by some deadly epidemic. If the old saying is right that "cleanliness is next to godliness," then the chemist stands next to the preacher, for he invented soap many centuries ago and has now added more powerful agents of purification, such as chlorine.

The automobiles which wait in front of the building are propelled by gasoline and oiled by lubricants manufactured from crude petroleum, and their wheels are tired with rubber vulcanized by the chemist.

In some large hall of the building you may very likely see motion pictures of events that happened far away and long ago, caught, preserved and displayed on celluloid film, made from gun-cotton and camphor and developed by coal-tar chemicals You may also hear music from unseen singers and players, permanently recorded for the pleasure of posterity, on disks of synthetic resin. The radio apparatus on the roof, almost entirely composed of chemical products, receives messages and music from a thousand miles away through trackless space.

So science short-circuits both time and space, bringing the past into the present and enabling us to chat with distant people as though they were in the room. And the chemist has a hand in all the achievements of science because he possesses the peculiar power of transforming matter into strange and useful forms. From colorless, odorless air and water he can make substances harder than marble, colors more brilliant than natural dyes, flavors rivaling the fruit, and perfumes as sweet as the flowers. For the chemist deals with the minutest things in nature. He can control the atoms, and even the electrical particles of which the atoms are made, and by combining these in various ways he can construct new things, unknown in nature, and contributing to the comfort and convenience of modern life in innumerable and unrecognized ways.

THE ADVANTAGE OF TAN

The Ethiopian cannot change his skin but the white man can. That is where the white man has the advantage, for when he is exposed to the sun he gradually becomes a colored man. (The negro is not a "colored" man; he was born so.)

The white skin automatically protects itself against the injurious action of the sun's rays by developing a layer of dark pigment in the deeper part of the epidermis. That is, the brunettes and the tannable blonds have this power. The incorrigible blonds that burn and blister will have to stay in the house or take to charcoal face powder.

Black looks black to us because it absorbs and keeps the visual rays of light. White looks white to us because it reflects them back to our eyes. White clothing is therefore better than black in the tropics because it sheds sunshine better. Black cloth absorbs about twice as much of the visible rays as white.

We might conclude from this that a white skin would be better than black in warding off sunshine. And so it would if heat were the only thing involved. But it is not. The sun's rays contain, besides the heat that we feel and the light that we can see, certain rays that we can neither feel nor see but which have a powerful effect upon the skin for good or ill. These are the rays that have a shorter wave length than the violet which are the shortest that can be seen. They are therefore called the "ultra-violet." Ordinary sunshine contains only about one per cent. of these ultra-violet rays; more if the air is dry, less if it is damp. Of the rest of the solar radiation about 19 per cent. is in the form of visible light and

Wide World Photos

A Large Family

Mrs. Martha Allbright Hankins, of Pine Bluff, Arkansas, who has recently celebrated her ninety-sixth birthday, is the head of the family. There were 245 members of the family present at this gathering to celebrate Mrs. Hankins's ninety-sixth birthday; 100 others could not attend. Among those who helped to celebrate the birthday were seven children, 62 grandchildren, 150 great grandchildren and 23 great-great grandchildren. Mrs. Hankins can be seen in the center foreground with a black bonnet.

about 80 per cent. in the form of dark heat or "infra-red" rays. The heat rays are absorbed about the same whether the skin or clothing be black or white.

But with the short-wave rays at the other end of the spectrum it is different. These are more energetic than the long-wave rays but are more easily discouraged and do not penetrate so far into the skin. If you hold up your hand and look through it toward the sun you will see that the light that gets through the thin parts of the fingers looks red. That means the long red waves, and of course the longer heat waves, go through the flesh while the short violet waves, and of course the shorter ultra-violet, are caught and held in the flesh

This is fortunate for the ultra-violet rays are fatal to the living cells of the body. The X-rays that have waves ten thousand times shorter than the ultra-violet are so powerful that they are used to burn away cancers. The visible rays of short wave length are still strong enough to cause sunburn.

What we need then in the skin is some sort of a contrivance that will take these short light and ultra-light waves and transform them to the harmless heat waves, what the electricians call a "step-down transformer."

Well, we have such a contrivance in tan. First the thin horny outside layer of the skin catches and converts to heat the ultra-violet Then the short-wave visible rays, violet and blue, are caught by the pigmented cells lying beneath. The longer waves, the yellow, red and infra-red, penetrate further but do no harm except to make us warmer. A thin-skinned person well tanned is better off than a thick-skinned person because the former is sufficiently protected against the lethal rays and yet get rid of his own internal heat more readily by radiation through his thin skin.

The tan serves a purpose other than mere protection. For the nerve endings lie between the pigment cells and when they are excited by the heat from the transformed light they dilate the vessels in the skin and so send out the sweat which by evaporation cools off the body

It seems that ultra-violet and violet rays may be positively beneficial when properly transformed by a coat of tan. Rickets and tuberculous sores are reported to be cured by the exposure to direct sunlight but not by that which has been passed through glass for this filters out the ultra-violet rays.

It is not necessary to carry the pigmentation to an extreme as the negro does. A good browning will insure against the injurious and secure the beneficial effects of sunning.

HOME-MADE RUBBER

It is to be hoped that part of the half million dollars that Congress has recently appropriated for developing a domestic rubber supply will be devoted to investigating the possibilities of home-made, as well as of home-grown, rubber. It is all right to start rubber plantations in the Philippines. If we had done that ten years ago we should not now be at the mercy of the British rubber-growers. Let us also milk the milkweed if it can be induced to give down. But let us further give the chemist a chance to see what he can do in the way of competing with the agriculturist. He has beat him on madder and indigo. Perhaps he can do it on caout-chouc.

We know that rubber can be made in the laboratory. At the International Congress of Applied Chemistry held in New York shortly before

the war the German chemist, Duisberg, proudly exhibited in the Great Hall of the College of the City of New York a pair of tires that had been made from synthetic rubber and had run an automobile a thousand miles or more. The British chemist, Sir William Perkin, promptly countered with a different process for making artificial rubber. Neither process has so far proved a commercial success but the chemists have not given up the problem.

Last year Plotnikoff announced in a German periodical that caoutchouc chloride could be readily made by the action of ultra-violet rays on vinyl chloride. Now the caout-chouc chloride can be easily converted into ordinary rubber and vinyl chloride can be made from acetylene which, as every automobilist knows or used to know, can be made by dropping calcium carbide into water, and calcium carbide can be made from coal and lime by the electrical furnace and the electrical power can be got from waterfalls

But where can we get the ultra-violet rays? There are plenty in the sunshine but they are pretty well filtered out by the atmosphere before it gets to us, luckily, for otherwise we would get worse sunburned than we do. The mercury-vapor lamp, such as makes us look like corpses when we are having our photographs taken, gives off ultra-violet but that is too expensive.

Now the ultra-violet rays differ from the rays that we can see only in having shorter wave lengths. Sometimes we see a tall man walking with his short wife, both at the same gait but she taking two steps to his one. So all kinds of light travel with the same speed in empty space but the violet takes two steps to the red's one, and the rays beyond, that is the ultra-violet, step faster still.

But a polite man will shorten his pace to accommodate the lady he is walking with, even if she is his wife. Can not light of long wave length be induced somehow to shorten its wave? In other words, can not ordinary sunshine be converted into ultra-violet light, or at any rate be made to act the same? It can in various ways, and Plotnikoff has shown that if a salt of uranium is added sunlight will serve as well as ultra-violet in effecting the transformation to rubber.

There is nothing absurd about making rubber with sunlight. All the rubber we use is made that way. And if a tree can use sunshine for that purpose why can not the chemist? We have plenty of sunshine, more than most countries and more than we want in summer. If there can be devised satisfactory step-up transformers to change sunshine into ultra-violet rays we might make not only rubber but a host of other things for which we now depend on plants, and we could use this energetic agent for speeding up numerous chemical manufactures. Dr. S. E. Sheppard in the February issue of the *Chemical Age* suggests that we might in time beat the plants in the making of various oils, resins, gums, sugars, dyes and drugs. The American Association for the Advancement of Science, foreseeing the immense future importance of knowing how to utilize the constructive power of light, has appointed a special committee on photosynthesis.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1923

THE UTILITY OF SOCIAL NUISANCES

By Professor KNIGHT DUNLAP
THE JOHNS HOPKINS UNIVERSITY

USING the word "nuisance" in its literal meaning of something harmful or injurious, I shall include under the term "social nuisance" any organized activity or propaganda which is of such nature that if it should succeed or prevail generally, it would produce social damage, either through a retrograde movement or the inhibition of progress in practical conditions of life, in the status of general knowledge or in social ideals. I shall raise the question whether these social nuisances, so long as they do not succeed or so long as they succeed in influencing only a safely small minority, do not actually have utility in forwarding the very things which they aim at obstructing or in accelerating the removal or suppression of the forces and conditions which they represent.

I wish to examine briefly, therefore, several familiar social nuisances and to inquire into their probable evil effects and possible good effects socially. While, for convenience and clearness, I shall state my points dogmatically, I wish it understood that in reality I am hoping merely to raise questions; and I find that the most certain and effective means of arousing in an intelligent audience a healthy questioning of theoretical statements is to make them bluntly dogmatic.

One of the most striking examples of a nuisance which has had a distinctly beneficial effect is Christian Science. Christian Science, if it should succeed in its aims, would not only abolish medical practice and remove the curative and sanative measures which have in modern times made so large a contribution to the amelioration of the conditions of life generally, but it would also abolish scientific research and stop progress in engineering and in the arts. It is true that the most persistent attack of this cult is upon medicine and that it for the present temporizes in regard to other applications of chemistry, physics and biology. Christian Science temples

are of material stone and brick, erected by the use of material means, and even heated with material coal and lighted by electricity: Christian Science farmers do not scruple even to apply chemical fertilizers to the soil. One may be astonished at this and wonder why the use of "material" means to stimulate the eye and to assist the bodily heat-regulating mechanism are not as wicked words of "mortal mind" as are the application of "material" means to relieve indigestion and to stimulate the heart One may stand aghast at the sublime inconsistency of a congregation of Christian Scientists of a summer evening cooling themselves with palm leaf fans; but we must remember that Christian Science has no worries over logical consistency, but dismisses logic as an evil work of "mortal mind."

Furthermore, these inconsistencies are not more egregious than certain temporizations in regard to medicine itself. By a general dispensation, Christian Scientists patronize dentists and obstetricians, although in theory these forms of medical assistance are in no different class from internal medicine, and in the thoroughgoing application of the principles of the cult no "material" means should be used to accomplish any result, the application of fertilizer to the soil being as great a lapse from "divine mind" as the application of quinine or a porous plaster to the animal body.

These inconsistencies cease to be sources of astonishment when we remember that the real animus of Christian Science, aside from its strictly religious and ethical points, is not against science, and really not even against medicine as a whole, but against *drugs*, or, in Christian Science terminology, against *materia medica;* and that the vagaries of the Christian Science theory with regard to the phenomenal world are merely naïve attempts to justify this animus, and its larger generalizations, even those against surgery, are necessarily only verbal and largely ignored.

Although we must admit that the effects of Christian Science have been very bad upon many of its adherents, both physically and mentally, we must nevertheless admit that it has contributed very substantially to the progress of medicine, and that society owes to it a debt of considerable magnitude. A generation ago, American medical men were in the habit of prescribing a great many drugs. Many of us can remember the various and nauseous decoctions and powders that were administered by general practitioners In fact, if the physician attending a sick man did not give him several kinds of medicine, the patient's family would hardly believe that the medicine man was doing his duty. A few of these medicines so generously administered were proven specifics: quinine for malaria; mercury for syphilis; ipecac to produce nausea;

with of course a long line of cathartics and laxatives, many of them of conjectural advisability. But the majority of the syrups, tinctures, extracts and other preparations had no more demonstrable efficacy in the general run of cases than had the potions and philters of the more primitive medicine of the middle ages and of savage tribes. The routine administration of medicines belonged strictly to the domain of magic and not to science. This type of medicine received its *reductio ad absurdum* in homeopathy, but its death blow was given by Christian Science. When patients unmistakably got well, not merely with the infinitesimal doses of the homeopathists, but even with nothing but the incantations read from Mrs Eddy's book of magic, the efficacy of the conventional slops began to be doubted, not only by the public, but by the medical profession. The more intelligent and progressive leaders of medical science, including in America such men as Sir William Osler and Llewellys F. Barker, found, therefore, a suddenly fertile field for their teachings. Physicians generally began to listen to scientific men in medicine, and to largely abandon the pill and powder and spoonful treatment, and to depend largely on common sense diet, good nursing and scientifically demonstrated remedies; and they speedily beat the Christian Scientists at their own game. Even to-day, when a great many specifics, antitoxins and other medical agents have been scientifically established, the amount of medicine administered by mouth is very small as compared with that given a generation ago. While it is true that Skoda and his followers in Europe, and Osler and his coadjutors here should have the maximal credit for this progress, we should not overlook the fact that homeopathy and Christian Science have aided them materially in putting medicine on a scientific basis.

Another nuisance which has menaced medical practice and scientific research is the antivivisectionist movement. In some places the antivivisectionists undoubtedly have cramped medical research and will cramp it more. But I suspect that, on the whole, animal experimentation has actually been helped by the antivivisectionists. This assistance has been rendered through the general care which they have forced upon physiology and pathology: care to do the necessary animal work under the most humane conditions, and care to avoid unnecessary work of a merely demonstrational kind; and care to explain to the public the necessities of the research. In this way, if animal experimentation has not actually strengthened its hold upon the public, it has at least obviated a very serious weakening of the hold which would have led to an uncontrollable landslide against it.

In another way the Christian Scientists, antivivisectionists, and more especially certain other antimedical movements, such as osteopathy and chiropractice, which would be disastrous if they should succeed, have been of social value. The tendency to regulate the lives of individuals in the most autocratic way has not been alone a tendency of the moralists, but has been shown at times by groups in the medical profession. Without denying that a minimal amount of regulation is necessary, we must also admit that the tendency to regulate always runs ahead of the knowledge requisite for proper regulation. In view of the general apathy of the public, which rarely awakens as a whole to the need of protecting its liberty until its liberty is taken away, it would undoubtedly be unfortunate if we had no continuous nucleus of antagonism to every new form of health and hygiene autocracy which appears. This nucleus supplied by the antimedical group, constantly watchful, constantly active, and having considerable financial backing, has helped to forestall movements which would have been not only inimical to the public welfare, but also to the progress of medicine itself. In legislative halls, these groups watch carefully not only encroachments upon their own fields of graft, but also other encroachments which extend the autocratic power of the medical profession. I have no doubt that, if these interests had not stood in the way during the last ten years, the openly expressed aim of certain medical agitators—to put the mental examination of school children in the hands of M. D.'s exclusively and to prohibit trained psychologists from administering the Binet-Simon and other tests which they have created—would have reached a successful issue already.

Aside from the medical problems, there is at present another nucleus representing a point of view and a propaganda which would have most unfortunate results if successful, but which in its present condition is essentially valuable. This nucleus is constituted by the pacifists. Undoubtedly the pacifists were a great nuisance during the war. It is obvious that if they had had their way then, they themselves would now be listed for military service under the German Imperial Government (or their sons would be), and their attempts to preach pacifism would be suppressed by firing squads. Nevertheless, their existence during the war tended to moderate extreme measures which would have been disastrous at that time and to-day is an effective force against the encroachments of militarism in various forms. I believe we would be much worse off than we are to-day if we had no unreasonable and violent pacifists. But, unfortunately, the same principle works here also in another way, and just as the fanatical advocates of "peace at any price" during the war threatened to be of direct assistance to militarism, so they have helped militarism since by helping to defeat the

league of nations and promoting entanglements in the way of disarmament treaties, whose pernicious effects are already being shown.

Another group of propagandists who constitute in many respects an intolerable nuisance have also been of social value in somewhat similar way. Whether we Americans shall succeed or shall not succeed in maintaining our rights of free speech and constitutionally guaranteed rights to work for changes in the laws and government remains to be seen; and while it may be that the existence of the so-called "Red" propaganda intensifies the efforts of those who are attempting to destroy our constitutional guarantees, nevertheless I believe that the public attention brought to these efforts greatly facilitates our chances of salvation, and that without the conflict with the "Reds" we would be in much more danger of having our liberties taken from us bit by bit, not awakening to the despoliation until it should be complete

Another nuisance of a somewhat different sort, but no less a nuisance, has been the antievolution propaganda of the "fundamentalists" which has reasserted itself during the last few years. This propaganda is obviously a highly organized and well-financed effort for which the silver-tongued Nebraskan is merely a mouthpiece. If this propaganda should succeed, it would not merely destroy freedom of investigation and freedom of discussion in regard to the doctrine of evolution, but would be a significant and momentous backward step toward the medieval ecclesiastical control which has had such terrible effects in the past in many directions of science. This propaganda has indeed attained a measure of success in a few places. But we need not fear its general success, and in the meantime it has done a vast amount of unintentional good. Three years ago only a small percentage of the general public had much accurate information about the doctrine of evolution as actually taught by the biologists, and all sorts of wild evolutionary doctrines were inflicted upon the public by unofficial would-be scientists to the prejudice of the real theories. Since the recent agitation commenced, there is vastly more popular knowledge in this whole matter. The expository books which have been well written by Conklin and other leaders in biology have been bought in vast quantities. Not only have these books been extensively read, but magazine articles by qualified writers have also been widely read, and public lectures by authorized biologists and geologists have been largely attended. This increase in knowledge, I believe, far outweighs the temporary adverse effects of the propaganda, and I do not doubt that the progress of acceptance of the doctrine of evolution has been greatly forwarded; and also that the promulga-

tion of the doctrine of evolution will be much more cautious and conservative, and hence more acceptable.

For a number of years, an influential group, for whom a well-known and vulgar evangelist was the figure-head, carried on a propaganda which finally attained to the level of a well-marked social nuisance. This movement was deplored by the better educated members of the ministry of practically all denominations; but the propaganda had such force and financial backing that the majority of these ministers did not deem it advisable to oppose it openly. It has been alleged that the general purpose of the propaganda was perhaps political: that it was financed by men who were interested in keeping labor quiet and who believed that "old-time religion" would be a good narcotic. This theory may or may not be true; but it is apparent that the propaganda did not attain a large measure of success in this direction, and it is of course possible that this failure was largely responsible for its decline.[1] Superficially, the results of the movement were unquestionably bad. Religion was held up to ridicule and lost not only in spiritual value, but also in prestige wherever it was soiled by this movement. But on the whole, perhaps, the movement seems to have done good. This type of "evangelism" was but a more flamboyant, more vulgar and more lucrative manifestation of activities which had long been widespread in the United States, and the focussing of public attention on the evils involved and on the comparative lack of valuable results has been extremely useful. Apparently, in those localities in which this mockery on religion was exploited, there has been a marked lessening of the minor activities of the same type, and I believe that the final effect of the movement has been an acceleration of religious progress through the inhibiting and discrediting of the forces and tendencies on which the propaganda built.

By many individuals to-day prohibition is considered a social nuisance, and by some it is magnified to the position of the greatest of social nuisances. It may be that the antiprohibitionists are right. I am not interested in either side of this argument, but wish to point out that, even if prohibition is a great nuisance, it may be nevertheless true that it has great social value. As a matter of fact, the question of the limitation of personal liberty is a very serious one. Few people to-day would contend that it is possible to maintain an organized society without a considerable degree of such limitation. Many persons claim, however, that this limitation should be reduced to its lowest terms: that we should limit the activities of individuals only in so far as these activities, if not limited, would to a

[1] This propaganda has again flared up in the south, and will doubtless have a beneficent cathartic effect upon religious conditions there, as it had in the north.

greater extent limit the activities of others. This has been supposed to be the fundamental principle of the Democratic party in the United States, scandalously as this party has flouted the principle from time to time.

The question of prohibition is bound up with the question of the suppression of the traffic in drugs, of the suppression of the traffic in women, of the suppression of gambling and many similar paternalistic or socialistic regulations. One result of prohibition has been a renewed questioning of this whole situation—a questioning as to the theories and means by which individuals may be deprived of their liberties and the extent to which such deprivation can justifiably go. While it is through prohibition that our attention has been so forcibly called to the evil effects of general law-breaking, to the questionable value of laws which can not be generally enforced, and the egregious effect of laws which are enforced only on the poor and those without political or financial pull, our analysis does not remain on prohibition alone in regard to these points. We have at last waked up to the fact that in many states (Maryland, for example) we have been long afflicted by Sunday laws which are universally broken, even by those who have banded themselves together in the "Lord's Day Alliance" to promote their enforcement; and which, when they are enforced at all, are enforced only on foreigners and others who are low in the social or economic scales. We have awakened to the fact that our laws against gambling are of the same nature: that we raid the African crap game, and the card game in the foreign quarter, but that we would never think of raiding bridge games in fashionable residences or poker games in influential clubs. We have awakened to the curious fact that large numbers of the same people who are violently opposed to the legal suppression of the dissemination of information concerning the manufacture of home brews and the sale of apparatus for such manufacture are also as violently in favor of retaining the present laws against the dissemination of information concerning means of contraception and the sale of instruments and materials for such uses.

Whatever we decide on the question of the percentage of alcohol which shall be permitted in beverages, whatever we decide about the drug traffic (and we must remember that bootlegging in narcotics has a volume in the United States far exceeding the bootlegging in alcoholic beverages), whatever we decide about birth-control, we shall probably, within a few years, advance our whole political and social attitude towards the application of restrictive personal legislation, and it may even be that we shall be able to dissolve the iniquitous union of church and state now existing in many parts of

the United States in defiance of the Constitution: an outcome which would far outweigh all of the alleged evils which prohibition has brought upon us.

There are several social nuisances whose evil influences and whose ultimate utility may both be open to doubt. In the case of college athleties, for example, it is difficult to make out at present the relative values of the good and evil effects, although I am optimistic here also. As at present organized, college athletics defeat the very purposes for which they were presumably introduced, namely, the offering to students of facilities for taking the proper amount of physical exercise and relaxation, and inducements to make use of the facilities. While there can be no question as to the desirability of this program, we know that college athletics work in exactly the opposite direction. The great urge is upon men to "come out" for teams and assist in upholding the standing of their college in athletics, and the whole emphasis is on "beating" the rival colleges. Hence men are not wanted on training squads unless they have superior physical capacity and if they can not give to the training more time than the serious college student can really afford The result is that the very students who most need physical exercise are excluded from these activities; and the financial strain of the organizations for the production of winning teams prevents the establishment of the facilities for reasonable general games and athletics. Moreover, a certain by no means negligible number of students who might benefit from their college work, but who have superior physical capacity, are forced into athletics by student opinion, or are drawn in by their natural inclinations and the surrounding enthusiasms, and come to grief in their studies, either getting little out of college or being eliminated entirely. This waste of good college material must be given a large weight in the debit column of college athletics. On the credit side, we, of course, must put the development of the group spirit, which is an advantage in itself, but which perhaps could be realized just as advantageously in the large universities through the maintenance of racing stables. Intercollegiate horse races would, from many points of view, offer superior advantages for the formation and maintenance of college spirit, and the stables would not cost any more than the football teams cost these universities, and furthermore would not entail the sacrifice of capable students to the intercollegiate Moloch. Another credit which is closely connected with the formation of group spirit is the offering of extra-curricular topics of interest and conversation; and athletics as now organized does offer this topic, even to the majority of students whose active participation is limited to buying tickets, sitting on the bleachers and smoking cigarettes.

Students, in their periods of relaxation from academic work, necessarily turn to non-academic topics of discussion; and team standings, scores and activities certainly furnish a more healthy topic than the topics which otherwise tend to occupy the interest of young men in reaction from work. There can be no doubt that college athletics are beneficent in these respects, and that the elimination of the intercollegiate contests without the provision of an adequate substitute would be unfortunate and perhaps demoralizing to the morale of our colleges. But it is by no means certain that harmless substitutes may not be found.

Another nuisance of extremely deleterious sort whose benefits are conjectural is constituted by the yellow press. The magnitude of this evil is well understood by those who read the Baltimore, New York, Chicago, Boston or San Francisco papers, and it is probable that the press in some of the less important cities is as near the sodium line as is the worst journal in the cities mentioned. The power of the press to-day, especially of the yellow press, is enormous and far reaching. It has grasped the essential psychological principle of propaganda, namely, that opinions are best put over with the minimum of argument and the maximum of repetition. Countless illustrations could be drawn from recent occurrences. Perhaps the finest illustration is the repudiation of Burleson and of his administration of the Post Office, which apparently was brought about by extremely interested parties, working through the press, which, without giving any data or arguments, produced its popular effect by the continuously and flamboyantly reiterated assertion, both direct and by implication, that Burleson's administration was inefficient, in spite of solid facts to the contrary.

Another power which the yellow press possesses, and which it exercises frequently, is the power of ruining or very seriously injuring any private individual they please by printing scandal about him. Statements made concerning any individual, however good his previous reputation, and however lacking in foundation the statements may be, produce their effect. Even those readers who have good reason to know that no dependence can be put upon statements made in these papers, have, nevertheless, the tendency to believe what they read when conflicting facts are not actually presented. The effects of the stories printed are rather permanent, and are not removed even by successful damage suits against the papers.

On the credit side for this perhaps greatest nuisance of all, there seems to be little. I do not know at present what can be said in favor of the yellow press except that it is an unfortunate result of a principle of freedom which we can not afford to give up. No one

has as yet suggested any method of curbing the yellow press which does not involve worse consequences even than those of the yellow press itself.

In converse relation to the yellow press stands another nuisance which seems to offer no compensatory utility: a nuisance which has by no means reached its climax but is rapidly growing is the censorship of the movies, of books and of other vehicles of publicity. So far as any one can observe at present, the censorship of books has an effect diametrically opposite to that which is officially intended. If the publisher of a stupid book which is not selling, and which is a financial loss, can get the New York censor to suppress it, the financial success of that book is assured. I do not know how this game is played: whether through the gullibility of the censors, or whether through some other avenue of approach; but certainly, certain publishers seem to have the knack of working it most efficiently. Of course, really salacious books which are interesting enough to have a popular appeal do not need to resort to advertising of this kind. The popular Freudian books, for example, do quite nicely without it.

The same game has been worked with signal success by theater producers. Plays no worse than successful and much praised comedies, but which are too dull to attract the public, have been able to attain financial success by adroit manipulation of the demand for censorship, even where no censorship was actually possible. This game has been worked most profitably in New York and Baltimore this winter.

Obviously the greatest field for censorship is in the movies, and it is here that it is reaching its maximal expansion. Little actual effort is being made to censor the stage, perhaps because it is assumed that persons who can afford to pay several dollars for an evening's entertainment have no morals worth "protecting"; but the ten to fifty cent patrons of the movies are objects of great solicitude. The opportunities for manipulation are greatest here, and the chances that any Board of Censors might have any intelligence in matters pertaining to their censorship are rendered minimal by the method of appointment. The result, of course, is that perfectly harmless and, in fact, laudable types of production are prohibited; and the producers are driven to types of production which are much more vicious than the ones interdicted; the more vicious movies being usually passed by the Board of Censors. I could give a very long list of actual occurrences in this line, but the facts are too well known to any intelligent audience to need elaboration. So far, I do not know of any good results of censorship carried beyond that ordinarily exercised by public opinion, and by a minimum of police

inspection, which can be set over against the egregious evils which censorship entails.

Municipal pride is one of the nuisances whose foundations and motives it is most difficult to understand. Why should the dwellers in a particular city be so intensely anxious to have the city grow, and take such vast pride in its enlargement, in spite of the fact that the growth means increased taxes, increased discomforts of living and losses in many other respects? It is a fact, however, that citizens will gladly tax themselves excessively, and put up with needless deprivations and discomforts, in order to glory in a fifty thousand, or a hundred thousand, or two hundred thousand superfluous population.

On the other hand, certain advantages undoubtedly flow from municipal pride. In spite of its general misdirection, municipal pride has certain useful applications in that it leads to an improvement of living conditions: it is interested in clean streets, the reduction of crime, improvement of health, and so on. The case here is perhaps theoretically simpler than in the case of the other nuisances. What is really needed is a redirection of municipal pride away from merely numerical ideals towards qualitative ideals.

Another nuisance which offers some difficulty in its understanding is the wide-spread tendency towards amateur dramatics which has had its *floruit* not only in occasional organizations and in college dramatics, but more extensively in the "little theater" movement. The pernicious effects of amateur dramatics are of course obvious, if not on the personnel of the dramatic organizations themselves, at least on the long-suffering small audiences which are dragged in through college or family affiliations, or through social ties. The benefits of the amateur dramatic movements are perhaps hard to find, but there are probably utilities here also. These utilities consist not merely in the furnishing of occupation to certain individuals who can not easily engage in more useful or more highly cultural forms of activity—which is, of course, a social good, just as are the basket weaving and other therapeutic activities of various institutions—but consist also in the increased appreciation of good professional dramatics and in the higher standards in demands on the professional stage resulting from contrast with the amateur performances.

When we come to the consideration of the more direct interests of psychology, we find at least two nuisances which loom large, and which have caused much concern: nuisances which are in part inimical to the increase of knowledge, but also in part have deadly practical results. The first of these is Freudianism. Freudianism has undoubted ill effects in the obstruction of knowledge. Its funda-

mental theory of the "unconscious mind" is an opiate and substitute for inquiry, strictly comparable to the mythological nature-divinities of ancient peoples. Just as these ancient people explained thunder, lightning and other natural phenomena by saying "it is the work of the god," and were therefore satisfied without inquiry into natural causation, so the followers of psychoanalysis (and their numbers are now legion) say of this, that, and the other phenomenon that psychology is attempting to investigate, "it is the work of the unconscious mind," and think it has been explained by this phrase.

In many other directions, also, the Freudian movement has temporarily checked the research tendency, particularly with regard to dreams and the interpretation of symbols. On its practical side, it has been made the cloak of various forms of malpractice, including the extortion of large sums of money from dupes; and its social consequences are by no means negligible.

But on the other hand, the ultimate effect of Freudianism will undoubtedly be beneficial. The denial of the need of inquiry into the causation of mental phenomena is stimulating increased energy in that inquiry. There are indications that a renewed emphasis on the investigation of dreams and the psychology of symbolism will shortly be observable. As a matter of fact, the Freudian doctrine of symbolism was lifted bodily from the work of Payne, Knight and Thomas Inman and a score of other investigators of past generations. The Freudians have done little more than supply the *reductio ad absurdum* to doctrines which have long been in existence, and which have been too easily accepted. I doubt whether the impetus to an effective scientific study of the history and nature of symbols would have occurred within this generation, or perhaps within the next, without the stimulus of the Freudian absurdities. Furthermore (and this is by no means the least of the benefits derived from psychoanalysis), psychologists have been rudely shaken out of the complacent condition in which their fundamental theories and methods of interpretation were, to say the least, chaotic. The revival of scientific method in psychology and the shaking off of the chains of the naïve doctrine of "ideas" is, I believe, due in part to the general recognition that the main Freudian doctrines are after all but further, and logical, developments of the introspectionalists' principles and methods. The proper perspective upon behaviorism has also been attained in part through the study of its affiliations with Freudianism, and the recognition that, after all, that which has finally survived in behaviorism is nothing new, nothing antagonistic to psychology, but merely one of the methods which psychology has been using for many years.

The second nuisance which is of particular importance concerning psychology is a hydra-headed affair, which has frequently been characterized as fake psychology, which includes the various forms of "character analysis" and methods of "character development" or the "development of personality," and the application of these and similar nostrums to commercial and industrial fields. Here, again, the resulting evils are not merely the dissemination of fallacious theories, but include to a large extent practical results. Business men have been plucked as shamelessly as the traditional farmer was plucked by the lightning rod agent. Moreover (and perhaps this is the worst effect of all), the application of legitimate psychology to commerce and industry has been very seriously interfered with. In many cases the men who are victimized by the fake psychologists "see red" at the very name of psychology thereafter. In one instance, under my observation, the directors of a large manufacturing company were for some time averse to the employment by their engineering staff of a psychologist to work on an important practical problem, because this concern had a year or so before been victimized by a fake "psychologist"; and to the directors, all "psychologists" looked alike. I may add that in this case the engineers' plan was finally adopted, to the great financial advantage of the company.

Now, in spite of these serious evils resulting from the activity of the vast number of fake psychologists in the United States, there are undoubted benefits resulting from their mischief. In the first place, greater interest and greater energy on the part of the psychologists have been drawn to the problems of commercial and industrial applications. I doubt very much whether we would have the strong research movement in this direction at the present time were it not for the counter irritant the fake psychologists have applied to us. Furthermore, greater care and accuracy in work and statement, greater conservatism in conclusion have been imposed upon the psychologists through the necessity of setting up a distinction between real and fake psychology. The activities of the American Psychological Association in looking into the cases of individuals on its membership list who have adopted the methods of the faker have been brought about by the need of trying to keep our skirts clear. On the whole, the flood of quackery in this as in other fields of psychology is probably a good thing for psychology itself and for the serious and scientific psychologists.

THE PHILIPPINES AS AN IDEAL SITE FOR A BIOLOGICAL STATION

By ALBERT W. C. T. HERRE, Ph.D.
THE PHILIPPINE BUREAU OF SCIENCE

THE lives and works of some biologists rise so far above the general average of accomplishment that they form in truth a series of beacons, illuminating the path of truth for those of us in whom the Promethean fire burns less brilliantly.

Perhaps the most notable quintet of the past generation was Darwin, Haeckel, Huxley, Wallace and Weismann, since the work of each was extraordinarily stimulating to human thought and activities in general, as well as to biology in particular.

It is a singular and most noteworthy fact that each of the above, as well as such a man as Humboldt, who achieved eminence in many diverse lines of scientific investigation, spent many years studying plants and animals in their native habitats in various parts of the world, but particularly in the tropics. Their studies of life in the tropics and the wealth of knowledge they gained from contact with the incredible richness of tropical faunas and floras gave them the solid foundation on which to rear temples of truth, instead of mere dreams and futile speculations. However much we may disagree to-day with any or all of those named, however much we may deem them to fall short of the truth as revealed to and by us, we must, nevertheless, admit that they were powerful and original thinkers, who based their theories and explanations upon a breadth of knowledge such as few of to-day possess. Again, we must say that this knowledge they gained primarily through life and study in the tropics.

With these and many other notable examples before them, it seems strange that so few biologists of the United States ever study in the tropics, even for a brief period. It is extraordinary that so few of them have no first-hand knowledge of the life so lavishly displayed in the greatest of all Nature's laboratories, the rainy tropics.

To argue for the value of marine biological stations is utterly superfluous, and many of our schools far inland make some sort of provision for training at one of the stations on either the Atlantic or Pacific coast. But none of our colleges or universities furnishes much opportunity for students to do either elementary or research work in the tropics, and as they practically never insist that their

embryonic research men must study in the land of perpetual summer, the tendency is for their biologists to become progressively narrower. The systematists (there are a few of those strange beings still extant) become more and more restricted in their range and are apt to look upon a field which Gray or Wood, Audubon or Baird studied long ago as the habitat of an unknown flora or fauna, and as a result to exclude from consideration other lands or even other parts of their own country. As for the workers in other fields proliferated from the natural history stolon so graphically limned by Professor Wheeler, they are sometimes in danger of forgetting that there is such a thing as outdoors at all, and tales of tropical life are to them but the faint penumbra of a once iridescent dream.

Let us rejoice that there are still a few bold and hardy spirits in the United States who venture far afield, even unto the tropics, although their studies and explorations are usually confined to the American tropics. As a matter of fact there are some Americans who have a worldwide field knowledge of their particular group, or a cosmopolitan understanding of the fauna or flora in which they are interested, but such biologists are few and far between, and are almost obscured by the mass of mental as well as physical stay-at-homes.

The botanical station in Jamaica, which should be thronged throughout the year, has attracted a few workers while the Guianan station so seductively portrayed by Beebe should be visited by ever-increasing numbers of biologists hungering for the strong meat so lavishly provided there. These and other stations already existent or yet to be created are vitally necessary if American biologists are to stand in the front rank, and must have adequate support.

But what about the old world tropics? What about the East Indian *Gebiet*, richest and most varied of all, everything considered? To what extent do our biologists appreciate the fact that under their own flag is a region unexcelled in richness and unsurpassed in the freshness and attractiveness of its biological problems?

For many years the Dutch have maintained their wonderful botanical station at Buitenzorg, and both botanists and zoologists have found there inspiration and fresh stores of knowledge. Just the other day the scientific press told us of the selection of Ké Island as a site for the new Danish tropical marine biological station. The European biologists are eager to travel half way round the world that they may enjoy the privilege of working in the wonderland hallowed by the explorations and studies of Beccari, Bleeker, Rumphius, Wallace and a host of other illustrious naturalists.

Just where do American biologists and American institutions figure in this and what effort is being made to emulate European

investigators? A few of our most eminent botanists and zoologists have travelled and studied in the East Indies, but not a single American college, university or museum maintains any kind of station in the Philippines, or even sends a single worker or student there to enlarge his experience and ripen his knowledge.

This, however, is not the whole story. It is bad enough that they do not support any sort of a laboratory in the Philippines, but apparently they do not want to do anything of the sort or even utilize the opportunities which have been offered them for almost nothing. Some time ago a letter was sent by Governor General Leonard Wood to the leading universities, museums and scientific organizations of the United States, offering the resources of the Bureau of Science in cooperation with them in various lines of study and research. With only a single exception all of them turned down the offer. One institution invested $250 to be used in collecting museum material; we have already sent them nine packing cases filled with specimens of corals, which cost them the large sum of $25. That money spent to maintain a fellow in the Bureau of Science for a year or to allot a traveling fellowship to the Philippines would repay incalculably the institution which did it seems impossible of comprehension by those who direct the affairs of educational and scientific institutions in the United States.

Perhaps it is in order to state briefly some of the features which make the Philippines an extraordinarily attractive field for the naturalist, whether he calls himself anthropologist, botanist, ethnologist, geographer, geologist, physiologist, zoologist or what not.

The Philippines, trivial specks as they may seem to the average American, in reality extend as far from north to south as from Canada to Mexico, with a breadth as great as from New York to Detroit. Of the nearly 7,100 islands and islets comprised in the archipelago, 466 are over one square mile in area, and about 400 are inhabited, while Luzon and Mindanao are each as large or nearly as large as Ohio. The land surface of the Philippines approximately equals that of the combined areas of the New England States and New York, and is almost as great as that of the British Isles, while the water surface comprised within the limits of the far-flung archipelago is 570,000 square miles.

Over this vast area of land and water, with its enormous and intricate coast line, it is self-evident that aquatic conditions, land and sea topography, can be by no means uniform. It is true that the whole region is in the tropics, but the great mountain ranges and the high sharp peaks scattered over the islands give an altitudinal range from half-submerged coral reef to a height of more than 9,500 feet. There is thus a great variety of climatic conditions

with all the diversity of plant and animal life which this makes possible, even though snow never falls and frost is unknown except to a few who live on the highest plateau of Northern Luzon.

Forty miles east of northern Mindanao is the greatest oceanic depth known, while the Celebes, Sulu and China Seas provide such an additional variety of life conditions that the marine fauna of the Philippines is richer than that of any other region in the world. To the Philippine shore line, which embraces every possible variety of coast, ocean currents carry aquatic life from far-distant parts of the Indian and Pacific oceans. Thus the fauna of the Red Sea, Zanzibar and the Marquesas is alike represented in the Philippines, while there is also a high percentage of endemic forms. There is not a single one of the larger islands which has been fully explored by naturalists or on which a single class of plants or phylum of animals has been thoroughly investigated. Anywhere in the islands one can, within a few miles of the coast or even of the largest cities, get into an entirely different environment which in many instances has never before been visited by a scientist or collector.

As a concrete example, in a few hours one can go from Manila into the mountains beyond Laguna de Bay and be in territory which is unknown to naturalists. Away to the northward it stretches for four hundred miles or more, a wild tangle of forested mountains, inhabited only by a few *remontados,* wandering Negritos, and two or three small and practically unknown pagan tribes. In other words, the whole northeast side of Luzon is a virgin wilderness, ripe for the scientific investigator.

Then there is the vast, half-explored island of Mindanao, so little known that as yet no trustworthy maps of it exist. At a height of 2,220 feet above the sea lies Lake Lanao, covering more than 110 square miles. Here, in a climate that makes mere existence a joy, is a rich harvest for the naturalist. For example, at one visit to Dansalan I obtained in the Moro market three new genera and a dozen new species of Cyprinidae. In the pathless mountain ranges and great forests which cover enormous areas in Mindanao one can study tropical organisms at all altitudes up to nearly ten thousand feet, dwell with tribes whose manner of living has hardly changed for a thousand years and observe the complex life of the jungle to his heart's content.

Just beyond Manila's front door, and but a few hours away, lies the large island of Mindoro, least known of all the Philippines. Right across from Batangas and very easily reached from Manila at any time of year is Puerto Galera, with its extraordinarily rich and varied "submarine gardens." Here would be an ideal spot for a marine biological station, for the coral reef swarms with an incredible variety and richness of animal life, including everything from protozoa to fishes.

Not only would students have an opportunity here to study a wealth of aquatic organisms such as no other region could surpass and but few equal, but not far away is the great peak known as Mount Halcon, rising to a height of over 8400 feet. This noble mountain, whose summit has been reached but once, offers in its jungles an amazing opportunity to both botanists and zoologists.

The best reason, however, for locating a marine laboratory at Puerto Galera, rather than at any one of a hundred other spots equally suitable, is its close proximity to the Bureau of Science at Manila. This brilliantly conceived institution has a large and very well-selected scientific library, especially rich in serial publications, which is not only unsurpassed in all of Asia and Malaysia, but is superior to that of most educational institutions in the United States In addition the Bureau of Science is equipped with first-class chemical, physiological and pathological research laboratories. Beyond doubt arrangements could be made whereby the treasures of the Bureau Library could be utilized by marine station students, while those taking up problems in physiology, pathology, parasitology, tropical medicine or biological chemistry, to mention a few lines only, could make arrangements with the Bureau of Science which would be of great, indeed invaluable assistance to all concerned. By a system of working fellowships, some of the specialists in the Bureau of Science could devote part of their time to a marine station, giving it the benefit of their local knowledge and hard-earned field experience.

Should a marine biological station be established in the Philippines by some American institution or group of institutions it is certain that no European or American station could offer its workers such a wealth of material or such an opportunity for broadening their mental horizon. Those returning to the States after a period of work here would have a richness of background and experience such as could be obtained nowhere else in a like period of time. Their ability to interpret life, to correlate its various manifestations, and to help carry the light of knowledge a little further into the realm of ignorance and darkness would be enormously enhanced, not alone for the time being but for their whole existence.

The tropics possess the greatest resources and offer the greatest opportunities to man of any part of the globe. The day will come when these will be utilized to the full and the seat of civilization will again be changed to the regions it once occupied and where it naturally belongs. All lands are beautiful in one way or another, and all lands have their advantages. Yet the biologist has most to learn in the tropics, where life attains its greatest variety and luxuriance, and accordingly should establish there his training camps for those who are to be officers in the army enlisted against igno-

rance. And of all the world the Philippines offer the most ideal site for a marine biological laboratory.

In Philippine waters is perhaps the richest and most varied fish fauna in the world, probably a tenth of existing species occurring in the seas, lakes and rivers of the archipelago. Not only do we find there the unrivalled littoral fish life of the East Indies, as well as the wide-roving or cosmopolitan pelagic fishes, but to these are added forms which stray over from the coast of China or wander southward from Japan So little known are the fishes of the Philippines that we never make a collecting trip without bringing in a new species, or something Rüppell discovered in the Red Sea nearly a century ago and which has not been collected since, or some fish hitherto known only from the South Sea islands.

When it comes to a knowledge of life histories, the food, breeding, migrations, diseases and other important matters concerning fishes, or their economic utilization and development, we have not even made a beginning.

At Puerto Galera, on the north shore of Mindoro, Professor Lawrence E Griffin secured in a short time as many species of reef corals as, and only one genus less than, the Challenger Expedition secured in its voyage around the world. Several of these are new and still undescribed. Further collections in other parts of the Philippines would give an amount and variety of reef corals such as can be obtained nowhere else. Their collection and study would be a matter of great practical utility. Corals may make or destroy harbors and thus powerfully influence commerce and the life of countless thousands, while their fundamental connection with the geological formation of the Philippines in particular and with much of the world in general is sufficient of itself to show the value of their study.

Hugh Cuming, who returned to England in 1840 with the greatest collection of mollusks ever taken to Europe, spent four years in the Philippines, where he obtained his rarest treasures. Later collectors have shown that the Philippines possess the richest land molluscan fauna of any region of similar area in the world, but we know little more of their marine shells to-day than was made known by Cuming's collections. There is good reason to believe that the marine molluscan fauna of the Philippines is the richest in the world.

As long ago as 1907 Zahlbruckner urged me to go to the Philippines to collect lichens, saying it was the least known region in the world. Wainio's partly completed publications upon Philippine lichens demonstrate the extraordinary richness of the lichen flora of these islands, while my own fragmentary collections show that for the most part it is still very imperfectly known.

In 1900, perhaps 2,400 species of flowering plants and ferns were known from the Philippines. To-day the number already discovered is not far from 10,000. The remarkable botanical work carried on for the past twenty years by Director E. D. Merrill, of the Bureau of Science, who alone has described more new plants than are known from New England and New York, has added enormously not only to our knowledge of Philippine plants but also to the general affinities, history and distribution of Indo-Malayan plants. Yet giant pandans, huge forest trees and hosts of more or less conspicuous flowering plants are waiting still for the botanical explorer.

On a tree in my yard in Manila quantities of larvae were making queer cones out of the leaves on which they fed, and in which they remained during the chrysalis stage. Observation showed them to be something entirely new, yet zealous entomologists have been collecting insects in Manila for generations. Anywhere in the forest or fields one may find numbers of strange new species of insects.

The very valuable study of the vegetation of Mount Makiling, in which Dr. William H. Brown worked out the relation between the environment and physical types at different altitudes, is an illustration of an entirely different type of greatly needed scientific work. And so the story might be extended into all the divisions of botany and zoology, for the harvest is even greater for the workers in other lines than it is for the systematist.

Large areas of the islands have never been mapped, and there is much work yet for the explorer. There are tribes almost or quite unknown, and everywhere there is a rich harvest for the ethnologist and anthropologist. There is no other region where one can study leisurely and uninterruptedly a cross section of racial, tribal and family life extending without a break right through the centuries, from the twentieth back into medieval time, and then farther and farther away until finally the dim prehistoric period is reached when men lived in tree houses or no houses at all, neither planted nor harvested, and knew nothing of either textiles or cereals. If we study these people not merely with toleration but with sympathy we can obtain a remarkable insight into the daily life of our own ancestry in the not very remote days when they were rude savages on the banks of the Thames or roaming the gloomy forests of the Baltic. After all, there is no essential difference between the Northmen who horrified the rest of Europe by their piratical raids and the Moros whose marauding forays struck terror into the hearts of all their neighbors within a thousand miles or more. So, too, the Moro datu or Filipino cacique of to-day rules his taos in essen-

tially the same way that a "robber baron of the Rhine" or a Highland Chief held sway over the lives and fortunes of his people.

There is really but one serious drawback to life in the Philippines, if indeed it can be called one. I was brought up in the land of the mocking bird and the wood thrush, the scarlet tanager and the ruby throated humming bird, where birds of ravishing song or exquisite beauty were abundant. I know the joy of matching one's skill against the rush of the leaping black bass below Copperas Creek Dam, or of luring rainbow trout from the icy waters of a glacier-encompassed lake on Mt. Baker. But when one stands in the cool tropical forest at dawn and listens to the marvelous liquid notes of luscious melody gushing from the bird orchestra, or spends his days gloating over the riches of coral reefs, he comes to the point where he hates to leave it all and wishes to stay there forever. For the naturalist the tropics do not mean *dolce far niente;* rather they fill him with inspiration and zeal to work constantly to the limit of his ability.

Of course some people fear the tropics because, forsooth, the sun shines or because of old superstitions and traditions which had their origin among the cold and foggy northlands of Europe and were due primarily to ignorance, prejudice and conceit. Our ideas on the subject were imbibed from European sources, principally English, all dating back naturally to the days when nothing was known of hygiene, sanitation, infection, the relation of insects to disease and the importance of intestinal parasites. The blunt truth is that in spite of all that has been said and written on the subject, as yet we know almost nothing about the effects of tropical climates upon people in general and the north European stock in particular. One author has written a book upon the baneful effects of sunlight upon northern white people, but has utterly ignored all the factors which so commonly slow down or incapacitate the people of the tropics. Yet, as a matter of fact, here in the Philippines the sunlight is not so intense nor for so many hours daily or yearly as it is over a vast area in the arid southwest and western parts of the United States. Neither is the heat so great here in the tropics as it is over most of the United States during a considerable part of the year. The Imperial and Salt River Valleys, the Sacramento-San Joaquin basin, the plains of Nevada or West Texas, the great corn belt, or the Yazoo cotton fields can all show months of temperatures far in excess of anything ever seen in the Philippines, while in the Mississippi Valley and Gulf states the heat is as great at night as in the daytime, so that suffering, sweltering humanity can get no rest. Here in the Philippines, where sunstroke is unknown, surely the climate is not more dangerous than that to which millions in the United States are already accustomed.

Even were the picture as black as it has been painted, should that deter the modern field scientist any more than it did the naturalists in days of yore? Beccari and Wallace both plunged into the East Indian jungles when nothing was known of the causes of diseases or how to avoid successfully malaria and other infections, yet they both lived to a very advanced age.

It is axiomatic that until we eliminate intestinal and other parasites, which in some places infest an enormous percentage of the people, and likewise overcome the effects of an impoverished diet, defective in variety and quantity, resulting in malnutrition or semi-starvation or both, we can know nothing of the results due to a tropical climate. It has been the mode to impute the lack of physical strength and the lack of energy of many people native to the tropics to the ill effects of the climate, when as a matter of fact they have been weakened by hook worm, malaria, filariasis, amoebic dysentery and other infestations and infections. It is, moreover, quite true that the greater number of those who fall victim to such diseases do so as a result of their wilful neglect of perfectly simple precautionary measures. Especially is this true of many Europeans and Americans, who deem themselves of superior clay to natives of the tropics.

Wherever we find native workmen sufficiently well fed and leading an active life we find them well muscled, capable of great exertion and able to do efficient work. One could not ask for better specimens physically than the longshoremen and sailors of the Philippine ports, or the lean hard Samals who not so long ago were the most dreaded of pirates. On the other hand, many of the tao and illustrado classes alike are miserably puny specimens, equally deficient in muscle and vitality. But this is due to many causes, some of them already cited, others having to do with social traditions and customs, but none traceable to climate.

Ever since white men began to make slaves of or to control the natives of warm countries, they have said, in order to bolster their position, that white men could not endure any form of manual labor in the tropics. Not only have our soldiers performed herculean labors in the regular performance of their duties, but the many American ranchers scattered all over the Philippines, often compelled to turn their hands to every form of the most arduous and exacting manual labor in their struggle against odds to subdue the wilderness and create productive estates, have shown that so far as physical welfare is concerned white men can do anything in the tropics that they can do in the United States and still maintain exuberant health.

In this connection it is well to observe that the eminent English authorities on tropical medicine, Castellani and Chalmers, state

that the most potent disability factor in the tropics is alcohol! Yet English tradition, sedulously cultivated by many Americans, has it that "You must drink lots of whisky and soda to keep in health in the tropics."

It requires slight observation to show that the natives of the tropics vary as do all people, and that a large percentage of the brown or yellow skinned people do not stand heat so well as do many white people. Any person who is in first-class physical condition can live in greater comfort and with less ill health in the tropics than he possibly can in Chicago, New York or Boston. If one eats plenty of wholesome food, using freely fresh native fruits and vegetables, takes plenty of exercise, takes the same precautions against typhoid and other infections that he would in most parts of the United States and lets alcohol alone, he will find his store of vitality not only maintained but augmented, and the human motor will neither freeze nor overheat but will be able to work with its maximum efficiency.

In conclusion, let us state the following propositions:

(*a*) The tropics are Nature's most wonderful laboratories.

(*b*) The biologist can learn more in the tropics than in any other part of the world in a like period.

(*c*) The Philippines have the richest aquatic life known.

(*d*) The Philippines are less known scientifically than any region of like area.

(*e*) A marine biological station should be maintained in the Philippines by a group of American institutions.

(*f*) Such an institution would have many advantages, not the least of which would be the opportunity for cooperation with the Bureau of Science.

(*g*) Such an institution would be a great factor in freeing American biologists of provincialism and ingrowing narrowness.

(*h*) It would have a tremendous influence upon the development of American biology and would give it added prestige.

(*i*) Properly conducted, a scholarship at the Philippine marine biological station would be considered the highest honor that a young biologist could attain.

(*j*) The college professor or foundation or museum worker would find that six months or a year in the Philippines would not merely rejuvenate his old ideas but would give him invaluable new points of contact.

Lastly, let us all take hold and make such a vision a beneficent reality.

INACCURACIES IN THE MATHEMATICAL LITERATURE

By Professor G. A. MILLER
UNIVERSITY OF ILLINOIS

SINCE the beginning of the history of science there have been some men who degraded their contemporaries in the eyes of future generations by recording their own ignorance. Many of those who have had the writing itch have been neither the best informed nor the most accurate observers of their own generation. The term "mathematical accuracy" is frequently used to denote ideal accuracy, and one of the most important elements in a mathematical training is the cultivation of such accuracy. The professional mathematician is compelled to employ a method of exposition which is naturally avoided as far as possible by other scientists, *viz.*, the method of basing many of his arguments upon results which can be derived from the postulates only by means of a long process of reasoning. His remoteness from these postulates makes it necessary to place full confidence in this long process of reasoning, for weakness therein would imply not only the danger of falling but also the danger of falling from such a great height that the fall would likely be fatal.

The great remoteness of much of the mathematical developments from the postulates on which they are based implies the safety of the intervening structure, and the fact that this structure could easily be made so safe, in turn, implies the tendency to venture so far away from the postulates in this particular field. A mathematician's thought can not be centered continually on his purely mathematical developments. He, too, has an interest in topics which do not yet admit of mathematical treatment. He, too, must deal largely with questions where it is not safe to venture far from the postulates and where it is not customary even to formulate these postulates explicitly. It is here where his mathematical training may become a handicap unless he distinguishes carefully between questions which admit and those which do not admit mathematical treatment.

A lack of such discrimination was noticed by Napoleon in P. S. Laplace, whom he appointed as minister of the interior but had to dismiss about six weeks later as a misfit for this position. As

Napoleon maintained that the advancement and perfection of mathematics were intimately connected with the prosperity of the state, and was unusually interested in mathematics for a man so deeply involved in politics, it is instructive to note his observations relating to the noted mathematician in question, which were as follows: Laplace failed to seize a question from the true point of view; he sought subtleties everywhere, having only problematic ideas, and he carried the spirit of the infinitely small into the administration.

During the last half century a rapidly growing number of mathematicians have become interested in the early history of our subject. This has become necessary in order to avoid duplication, and to secure greater unity and a clearer insight into the fundamental tendencies of the rapid advances made during this period. Even in this field the mathematician soon discovered that he could not always proceed with the degree of certainty which characterized his work in pure mathematics. Not only are many questions of fundamental importance relating to the early developments of mathematics involved in contradictory records and in records which are entirely unreliable, having been made by people who had not yet acquired the art of accurate observation, but even many of the more modern historical questions have such extensive ramifications that it is extremely difficult to make brief and fundamental statements about them without the danger of conveying incorrect impressions.

The human race seems to have always permitted a considerable digression from the truth for the sake of producing certain effects supposed to be wholesome. Inaccessible and unexplored regions have been allowed to furnish the imagination much food, which frequently served to awaken thoughts of a more or less serious type. In nature these regions have become more restricted, and in the thought world the extensive scientific literature has equally contributed towards substituting realities for vague imaginations as objects of thought. It seemed to me that the history of mathematics should not be allowed to lag behind in this slow but sure progress towards reality, for the truth is to make us free. Moreover, it seems that the university instructor should try to help those teachers who have had less opportunity to use good libraries.

Historical fiction has probably never been relatively less popular than it is in our days. Just as many pulpit orators of our times express their indifference as regards the literal accuracy of historical statements which seem to be fraught with spiritual significance, so many of our teachers are practically indifferent as regards the authenticity of such interesting legends as the sacrifice of a hecatomb by Pythagoras or the solution by the young Des-

cartes of a difficult challenge problem which is said to have attracted the attention of the public in Breda, Holland. Even such an authoritative work as the eleventh edition of the *Britannica* refers, under the name of Descartes, to the latter as if it were a well-established historical fact. The growing popularity of mathematical history has afforded an unusually large number of temptations for presenting fiction in place of established facts in case the latter were not known to the speaker or writer.

Few would probably be inclined to defend statements which are evidently incorrect. For instance, if one reads in a history that J. Ch. Burckhardt died in 1815 and notes in the following line that he published a factor table in Paris in 1817, one is willing to admit that at least one of these dates should be changed. Men are not known to have published mathematical tables after they were dead, even in such a mathematical center as Paris. Similarly, when one reads that De Moivre extended "the theorems on the multiplication and division of sectors from the circle to the hyperbola," one is willing to admit that historical statements should mean something, notwithstanding the fact that a statement similar to this appears on page 200 of volume 7, Marie, "Histoire des Sciences Mathématiques." As an instance of evident inaccuracies of much larger historical significance we may refer to the following statements: "It is to be observed that in Diophantus, and in fact in all writings of antiquity, the concept of *quotient* is wanting. An operation of *division* is nowhere exhibited. When one number had to be divided by another, the answer was reached by repeated subtraction."

Just as the term division has two distinct meanings in elementary mathematics so the term quotient has two distinct meanings. When the remainder is zero these two meanings practically coincide, and it seems reasonable to assume that this special case was first considered. The early appearance of fractions in the Babylonian and the Egyptian mathematical literature points to the very early use of division as the inverse of multiplication, but one concept of quotient is independent of this use. It is, therefore, very far from the truth to say that concept of quotient is wanting in all writings of antiquity and that the operation of division is nowhere exhibited. A quotient obtained by repeated subtraction is just as much a quotient as if it had been found by the inverse of multiplication, but even if the latter were the only meaning of quotient the quotation under consideration would evidently be misleading.

A historical statement frequently met in the accounts of the work of Galileo is as follows: "Up to his time it was believed that a cannon-ball moved forward at first in a straight line and then

suddenly fell vertically to the ground." That this belief was not universal up to the time of Galileo results from the fact that Tartagila, in his *Nuova Scienza*, 1537, contended that the path of a projectile is curved in every part. This quotation seems to me to be a great reproach on early human thoughtfulness, for what boy has not noticed the paths of stones thrown by himself or his playmates. We owe it to the respectability of our forefathers to modify such statements as far as possible in harmony with historical evidence. The glorification of a few at the expense of the rest of mankind is neither sane nor democratic.[1]

The accuracy in mathematical history which is under consideration relates however mainly to a different line of thought. What we have in mind is the most effective degree of accuracy. The question may be raised whether the accuracy to which the pure mathematician is accustomed should characterize his work in mathematical history or whether he should allow himself here greater freedom as regards the use of statements which are only approximately true. A partial answer to this question is perhaps furnished by the fact that a mathematical history should be constructed with a definite view to the needs of the readers for whom it is intended, and that we should have not only one type of such histories, but various types so as to reach most effectively a large body of readers. Some readers would appreciate the precise statement that "a necessary and sufficient condition that a regular polygon of n sides can be constructed by means of ruler and compass is that the order of the group of isomorphisms of the cyclic group of order n is a power of 2," while to others this statement would be meaningless.

In each type of histories every statement should be clear and definite and the explanations should be as complete as the available space permits. It may be desirable to make many historical assertions which can not be definitely proved, but these assertions should be in the nature of hypotheses which are in accord with all known facts and which are supported by a large number of facts which might otherwise appear unrelated. For instance, the assertion that the ancient Greeks did not use negative numbers can clearly not be proved definitely, but it is commonly accepted as a legitimate statement. On the other hand, the assertion is frequently made that the ancient Greeks considered only one root of an algebraic equation even when such an equation has more than one positive root. This is a more questionable assertion since Archimedes considered the condition under which a certain cubic equa-

[1] F. Cajori, "A History of Mathematics," 1919, pp. 172, 229, 440. See also "A History of Elementary Mathematics" by the same author, page 37 of both editions.

tion has more than one real root.[2] This is, however, an exceptional case in the Greek literature that has been preserved.

Many of the leading mathematicians have made broad historical statements which are very useful even if it is impossible to prove them. Among these is the following remark made by G. Darboux, "Oeuvres de Henri Poincaré," volume 2, page xxiv: "Among all the discoveries which the mathematicians have made in the course of the nineteenth century, the most fertile without doubt is that which is due to Cauchy relative to Taylor's series and to the conditions of its convergence. One may say that it has renewed all branches of analysis." As the nineteenth century is so rich in fundamental mathematical discoveries it might appear bold to pick out one and to ascribe to it such a preeminent position as is here done. On the other hand, it is scarcely possible to lay too much stress on the importance of the particular discovery in question, and such statements, emanating from high authority, are read with great interest and profit even by those who would not be willing to endorse them unreservedly. Some statements are very useful, even if they are not true as regards all details.

As another instance of a broad historic statement by one who was not a professional mathematical historian we may quote the following due to S. Lie: "While the curve as the representation of a function of a single variable has been the most important object of mathematical investigation for nearly two centuries from Descartes, while, on the other hand, the concept of transformation first appeared in this century (the nineteenth) as an expedient in the study of curves and surfaces, there has gradually developed in the last decades a general theory of transformations whose elements are represented by the transformation itself, while the series of transformations, in particular the transformation groups, constitute the object."

It is desirable to distinguish between mathematical history and mathematical archeology. The mathematical historian must understand broad fields of mathematics and must be able to discern the broad tendencies as well as some of the main details. On the other hand, the mathematical archeologist needs to know but little mathematics and may properly limit himself to details which are of comparatively little interest to the mathematical historian. A collection of old MSS. and of old arithmetics or of old pictures of men about whose physical features we know nothing is more suited for the laboratory of the archeologist than for the study of the historian, although the latter is sometimes in need of the results ob-

[2] *Cf.* T. L. Heath, "The Works of Archimedes," 1897, CXXVII; F. Cajori, "A History of Mathematics," 1919, p. 61.

tained by the former and will naturally be greatly aided by an understanding of some of the details relating to the work of the former, but it is unfortunate that this work is so widely confused with true mathematical history.

We stated above that Napoleon dismissed Laplace from the position of minister of the interior at the end of about six weeks. Those who are familiar with Netto's account of the affairs in Volume 4 of Cantor's "Vorlesunger über Geschichte der Mathematik," page 228, may recall that it is here stated that Laplace was dismissed after six *months*, and that the same error appears on page 260 of the second edition of Cajori's "History of Mathematics." At the latter place it is also incorrectly stated that Napoleon was made emperor on the 18th of Brumaire, referring to the notable day in French history when Napoleon practically seized the reins of the government in 1799. He was, however, not made emperor until 1804. It seemed desirable to refer to these details, since otherwise some might be led to believe that the statement made above was due to an oversight. It may be added that the term "divergent series" was not used by James Gregory as stated on page 228 of the latter work and that the figure which appears on page 326 thereof does not relate to Bolzmann's "H-curve" as there stated but to the well-known curve described by Koch. Moreover, the assumption that "in any circle the inscribed equilateral quadrangle is greater than any one of the segments which lie outside it" can obviously not be regarded as a simpler and more obvious axiom than the parallel axiom, as stated on page 302.

Accuracy in mathematical history implies an exhibition of the central thoughts in their true relations and hence it implies mathematical insight of the highest order. The greatest mathematicians have also been the greatest mathematical historians in the sense that they first exhibited the fundamental relations in the proper light. One follows the thoughts of such men with a growing insight because of their accuracy. Such accuracy is of much greater importance than the accuracy relating to details, such as exact dates or exact references. In particular, one seldom reads an *aperçu historique* in the "Encyclopédie des Sciences Mathématiques" without feeling inspired by the clarity resulting from the accurate formulation of fundamental thoughts. This type of accuracy is of the greatest importance in mathematical history because the trains of thoughts awakened thereby connect many hitherto distant facts and present one of the feasts of harmonizing thinking, so much prized by those accustomed to mathematical meditation. That even eminent mathematicians are not always en-

tirely successful in this direction may be seen from Klein's criticisms of his own noted Erlangen Program.[8]

A serious handicap in the development of a reliable general history of mathematics has been the fact that the earlier parts of such a history are largely based on mathematical archeology, and this subject is comparatively young. It is mainly due to this fact that our general histories of mathematics have so soon become out of date. Even the history of Montucla and the history of Cantor were soon pronounced behind the times, and one consults these works now with the understanding that much that is contained therein must be modified in view of later discoveries. Great impulses for the study of mathematical archeology were furnished about the beginning of the nineteenth century by the discovery of the famous Rosetta stone, the deciphering of cuneiform inscriptions, and the appearance in Europe of a Sanskrit grammar. The later discoveries in regard to the Maya of southern Mexico have led to some striking results relating to the arithmetic of the aborigines of America.

The general subject of accuracy in mathematical history seems to have been endorsed by the American Mathematical Society in view of the fact that the older official journal of this society is called a "historical and critical review." This is a somewhat bold position to take, since a really critical review often contains statements which are disagreeable to the author. In the oldest German mathematical periodical which survived, the editor explicitly stated in the preface of volume 2 that everything which could hurt any one was unconditionally and strictly excluded. It is interesting to note that the American Mathematical Society, at least in theory, assumed a bolder attitude. The explicit association of the terms historical and critical should be noted. While neither of these terms implies the other, the literature described by one is apt to have an element to which the other applies.

There is a very wide difference between directing attention to inaccuracies in a book and expressing an unfavorable opinion of it. There are comparatively few books which do not involve known inaccuracies and some of the best ones contain more inaccurate statements than others which are much inferior but whose authors were skilful in hiding their own ignorance. Moreover, all agree that serious inaccuracies should be corrected and that an open and frank discussion of such inaccuracies is often very instructive. We are glad to forgive such sins, but we would like to know something about the sins which we forgive. There are also many questions

[8] Felix Klein, "Gesammelte Mathematische Abhandlungen," Vol. 1 (1921), p. 414.

where differences of views exist and it seems undesirable to try to make all agree as to details. Intellectual combats are at least as wholesome and as invigorating for youths as the physical ones and their existence is only a sign of normal life. Even the most stalwart members of the church sing with great enthusiasm "Onward Christian Soldier," and those who shriek when they see a mouse often adore the man in a soldier's uniform.

The approximately fifty thousand mathematical books and pamphlets which have been published may be regarded as so many largely helpless children They can, however, not mend their own ways like other children can. Most of their authors are dead, and those who are still alive in many cases claim that they could do much better if they had another chance These books reflect shortcomings which many of their authors outgrew but which they themselves can never outgrow. While they may, therefore, excite our pity and incite us to do our best to make their faults harmless they constitute nevertheless our greatest time-binding heritage.

Although their authors may continue to have paternal interest in them long after their publication, they themselves begin to exert public influence from the time of their publication and it becomes then the duty of the public to see to it that this influence is wholesome. This is usually done by means of reviews which direct attention to their merits, if they have any, and warn those who seem to be in danger of being misled by possible demerits.

The reviewer of a book becomes a kind of father-in-law thereof, willingly or unwillingly as the case may be. In either case he is apt to learn much more about the book after preparing the review than before. He may even find it desirable to try to modify the impression which his review conveyed to the public, especially if the book is of such a nature that a considerable portion of the public reached by it is not in position to discover easily the needed modifications, as is likely to be the case in a historical work.

Mathematical history reveals certain invariants in human thinking which are of great interest in the study of the intellectual development of the human race. Some of these invariants were formulated by the Greeks and were called "common notions" in Euclid's "Elements." Long before such a formulation one notices invariants in mathematical thinking. For instance, in measuring it was always recognized that areas, such as those of rectangles and triangles, should be measured by square units having a linear unit for a side, and that volumes, such as those of prisms and pyramids, should be measured by cubical units having a linear unit for an edge and therefore square units for their faces. Even the work of Ahmes and the writings of the early Babylonians give evidences

of the use of such units, and later writers proceeded similarly. It is true that there are also instances of units of surface which are not squares such as our acre, which is a rectangle whose sides are 22 yards and 220 yards, respectively, and the Chinese unit rectangle whose sides are 1 and 6 tchis, respectively, but in these cases square units are also used. Such units constitute clearly the simplest of conventions since they give rise to easy rules, and we have here evidence of the influence convenience has exercised in the development of our subject.

These evidences of the invariance of human thinking raise the question whether the human mind has improved as regards mathematical thinking during historical ages. The crude mathematical thinking displayed by some modern writers when referring to mathematical subjects seems to furnish little evidence of general improvement. It is true that there is more accurate mathematical thinking now than there ever was before, but this difference seems to be more largely due to training than to native ability. Mathematical capacity grows by use, and the opportunities for this use have always existed. There are still many who would readily accept the statement that the perimeters of similar fields vary as their areas, and the inaccuracy of the mathematical thinking of a Gerbert, later Pope Sylvester II, has been equalled by some mathematical historians who dealt with his works and gave him too much credit, especially for his letter to Adelbold.[4] The main historical significance of this letter is that it exhibits the great mathematical weakness of the Romans, and of Gerbert in particular, near the end of the tenth century, but references thereto found in several of the most popular general histories of our subject give a very different impression.

Those who are inclined to believe in the mathematical superiority of the modern human intellect are confronted with one serious obstacle by the history of our subject, *viz*, the work of the Greeks. If the work of the Greeks and that due to its influence could be removed from the mathematical history of ancient and medieval times this history would apparently be reduced more than 90 per cent., and would be almost confined to practical methods of calculation and measurement. The astounding monuments created by the works of Archimedes, Apollonius and Euclid are not excelled by those due to the work of modern intellects if we make allowance for the higher ground upon which the latter stood. While we cordially grant to the Greeks the most prominent position in ancient

[4] See *School Science and Mathematics*, Vol. 21 (1921), p. 649. A discreditable feature of this letter is that it aims to replace a fairly accurate method of approximation by one which is much less accurate.

mathematical history we are keenly aware of the fact that their early work makes it difficult to support the theory that elegant results in pure mathematics are appreciated by all future generations. In fact, it is probable that comparatively few of the Greeks understood the work of their mathematical giants. The later mathematical retrogression may have been largely due to the fact that real mathematical attainments among the Greeks were too isolated.

One might at first be inclined to conclude that the numerous errors which appear in some of our popular general histories of mathematics and were carried over into new editions of these histories are evidence of a lack of a keen appreciation of our subject on the part of the modern reader. Keen appreciation implies that our thoughts dwell on a subject until the connections with others become clear, and error is apt to exhibit itself during this process. Unfortunately, few of those to whom these errors have thus exhibited themselves found it convenient to make their knowledge along this line useful to others, since they were more deeply interested in other phases of our subject where they could render needed service. As long as the general histories of our subject were read by comparatively few this course was perhaps natural, but with the increase in the number of readers in this field there comes also an increased need of service along the line of accuracy.

It is a singular fact that notwithstanding the great difficulties inherent to the history of our subject nearly every teacher of mathematics thinks that he can teach this history. Many are those whose mathematical knowledge is very inferior and yet they offer courses in the history of our subject. Frequently such courses are largely devoted to mathematical archeology. Several years ago Eneström noted that the secondary teachers of Sweden were not prepared to give reliable historical information in connection with their mathematical courses and hence they were properly not advised to furnish such information for the purpose of making their courses more attractive. Is it not time to warn the American teachers of secondary mathematics that they too are in danger of doing more harm than good by trying to impart historical information which they are in no position to verify as regards accuracy? The references to inaccuracies noted above may perhaps serve to initiate such a warning in our land.

The need of this warning might be illustrated by statements found in some of our best textbooks. In particular, the second paragraph of the introduction of such a work[5] begins with the following sentence: "Algebra, on the other hand, was unknown to the

[5] Osgood and Graustein, "Plane and Solid Analytic Geometry," 1921.

Greeks." If one consults the "History of Greek Mathematics" by Sir Thomas Heath, which appeared during the same year as the textbook in question, one finds that practically all of Chapter 20 is devoted to Greek algebra, and that some earlier pages are devoted to the geometrical algebra of the Greeks. It is true that it would be possible to define algebra in such a way as to exclude the work of the Greeks from this subject, but this is not commonly done, and hence the quotation noted above is likely to mislead the student. In fact, it is followed in the same textbook by the equally misleading statement that the beginnings of algebra are found among the Hindus. H. Hankel expressed a somewhat similar view, but Paul Tannery and others have pointed out that Hankel gave undue mathematical credit to the Hindus.[6]

The work of the mathematical historian is made more difficult by the frequent use of the same term with different meanings. Even such a commonly used term as "Euclidean geometry" has at least three different meanings in modern mathematical works of reference. In some of these the term is used with the meaning attached to it by Gauss, *viz.*, as any geometry in which the parallel postulate is assumed, while others use it as the geometry of the invariants under the group of transformations under which the distances between every pair of points is an absolute invariant. This is done, for instance, in the French mathematical encyclopedia, Tome 3, Volume 1, page 344. On the other hand, in such a reliable work of reference as the second edition of Pascal's "Repertorium der höheren Mathematik," Volume 2, page 61, the term "Euclidean geometry" is used for the geometry of the invariants under the principal group of geometry which includes also the similarity transformations and hence does not leave distances unaltered. The angles are, however, absolute invariants under this group.

Mathematical inaccuracy is closely related to mathematical indefiniteness. Such indefiniteness may confront the mathematical student very early in his career. For instance, in some elementary algebras he is told (properly according to my view) that such a relation as $9-7=2$ is an equation, while in others he finds the assertion that an equation must always involve a symbol to which we can assign a value and thus arrive at an identity. In some textbooks he is told that a determinant is a certain polynomial, while in others he finds that what is commonly known as the matrix of a determinant is the determinant and that it *represents* a poly-

[6] Paul Tannery, "La géométrie grecque," 1887, p. 6. See also three lists of marginal notes on the second edition of Cajori's "History of Mathematics," published in *School Science and Mathematics*, Vol. 19, p. 830; Vol. 20, p. 800; Vol. 23, p. 138; *Cf.*, *School and Society*, Vol. 16 (1922), p. 449.

nomial. Professor Bôcher criticized Kowalewski in the *Bulletin of the American Mathematical Society, Volume* 17 (1910), page 139, for using the word determinant frequently in the sense of matrix, adding that "this error is so sanctioned by universal usage that it must, for the present, be regarded rather as a defect of the age than of the individual." On the other hand Bôcher himself speaks of the rows and columns of a determinant within two pages after defining it as a polynomial. It is possible but not customary, as I understand it, to associate rows and columns with a polynomial regarded either abstractly as a function or concretely as the algebraic sum of monomials. It may be that the defect of the age is that we do not have a satisfactory accepted definition of the term determinant. This term need not be restricted to a polynomial alone nor to a matrix alone but it may represent a combination of the two. From this point of view a determinant does not represent a polynomial but the matrix of the determinant represents this polynomial. Similarly, the polynomial implies a square matrix if it is regarded as the polynomial of a determinant.

The author of the present paper does not feel certain that all contradictions should be eliminated from the mathematical literature, but he feels quite certain that the student should be informed as regards the existence of contradictions. This has not always been done. The history of the Archimedian postulate proves that at least since the time of the ancient Greeks mathematical treatments have sometimes been made easier by denying the existence of what seems evident but may be denied without getting us into practical difficulties, as is done in assuming that all right angles are equal. The fact that contradictory definitions of such common terms as equations, determinants and circles have persisted without causing much embarrassment tends also to support the view that mathematical progress may have been aided by the existence of some contradictions in its literature. Even the mathematician may gain by construing words to fit their surroundings instead of regarding them as being independent of their positions. In fact, he should frequently read the truth into false statements, but he can scarcely be expected to overlook the fact that the statements are actually false. For instance, when one reads in Netto's "Gruppen und Substitutionentheorie," 1908, page 147, that every regular transitive group is imprimitive one sees easily that the group of prime order is to be excepted, but one should not be expected to regard the statement as correct.

The author of the present paper has perhaps been unusually credulous. At any rate, he has been led into many a mathematical trouble by relying upon the accuracy of statements found in works

of good reputation which he found afterwards to require modifications of various degrees. He has been led to feel that his path would have been easier if he had been warned, especially as regards the unreliability of many commonly accepted statements relating to the history of mathematics. Perhaps there are others who will profit by such a course. Hence the present note of warning. In view of the fact that the mathematical literature is probably more accurate than that of any other large subject our intellectual road is beset with comparatively few of such pitfalls as we have here and elsewhere aimed to mark by red lights. The few so-called replies which have appeared do not seem to prove that any of these lights mark a clear road.

CONSERVATISM AND RADICALISM—SOME DEFINITIONS AND DISTINCTIONS

By Professor A. B. WOLFE
UNIVERSITY OF TEXAS

MANY years ago, Walter Bagehot[1] showed how necessary it is for every social group to acquire what he called a shell of custom—some form and organization of authority to hold the group together in physical and spiritual solidarity and to curb the self-will of individuals who might endanger the cooperative cohesion and defensive powers of the group. But, as Bagehot goes on to suggest, once this shell of custom has set, it has sooner or later to be smashed, else it will stifle the growth and strangle the intellectual and moral evolution of the very society it was designed to serve. As a rule, when the provocation has become sufficiently great, men have risen who have not been lacking in the necessary courage and strength of character to undertake the task. Always, indeed, there have been would-be shell-smashers, men who rebelled inwardly or outwardly, and frequently with violence, against the particular controls and institutions imposed by historical accretion, by the passive, non-resistant indifference of the phlegmatic or repressed masses and by the special interests of powerful individuals or classes.

Thus sponsors of things-as-they-are and advocates of change, modification and transformation are always set over against one another in an attitudinal and active conflict, the intensity of which depends both upon the psychological temperament and character of the two groups, conservative and radical, respectively, and upon the degree of divergence or opposition of their respective interests.

The scale of attitudes which different men and women take toward social change may be compared to the solar spectrum. At the opposite ends stand extreme radicalism and uncompromising reaction. Between these extremes are conservatism and liberalism, or progressivism, each with its various degrees of intensity and its shading into the adjacent attitudes. Thus the attitudinal spectrum reads, from left to right, radicalism, liberalism or progressivism, conservatism, reactionism. Like the colors in the solar spectrum these attitudes grade each into the next so gradually that it is impossible to draw a sharp line between any continuous two.

[1] "Physics and Politics," 1873, Ch. 1.

Conservatism, generally speaking, is simply that system of sentiments, that mental attitude, which causes the individual to accept with equanimity and approval things-as-they-are (or would be if liberals and radicals would only let them alone), which desires little if any change, and which opposes with vigor any proposal for radical transformation. In its purest form conservatism regards whatever is as right and final. The typical conservative opposes not so much relatively innocuous temporizing and tinkering with unimportant social details, and not so much the evolutionary drift which may mean in the long run very significant transformations, of which he is ordinarily oblivious, as he does thorough-going and consciously conceived and directed reform or revolution having to do with the more fundamental aspects of thought, economic organization, and social relations. Conservatism, if it could have its way, would thus stand still, maintaining social relations and processes, thought, belief and culture practically as they happen to be at the time, and resisting, on the one hand, the innovations of progressive and radical, and on the other, with perhaps a little less enthusiasm, the reversionary ideals of the reactionary.

With reactionism the conservative is not in accord, because reactionism would return to some previously current but now abandoned mode of thought and system of organization. The reversion advocated by the reactionary is distasteful to the conservative since it would mean a change in relations and activities which would interfere with his habituation and attachment to things-as-they-are. Nevertheless, the thorough conservative is more nearly related to the reactionary than to the radical. Conservatism is opposed to radical thought and action, and is antipathetic to liberalism, because the conservative not only is averse to change of any significant kind, but has a lively fear of the new and unfamiliar. Both the introduction of new and unfamiliar arrangements and a return to some previously existing order involve change, and hence more or less disturbance of established habits and points of view. Both entail discomfort to the conservative, therefore, but the proposals of the reactionary are likely to seem less subversive than those of the radical, although as a matter of fact they may be quite as much so. The conservative does not want the existing shell of custom smashed or even appreciably bent, but if its form is to be modified at all he would rather go with the reactionary back to the tried and familiar than with the radical and his innovations.

Progressivism stands midway between conservatism and radicalism and partakes of the milder characteristics of both. The progressive welcomes and works for orderly and gradual changes which can be brought about by planned endeavor and the conscious

direction of social evolution. He is not so deeply habituated to things-as-they-are as is the conservative nor characterized by the irrational fear of change which marks so many timid temperaments. But progressivism is not devoid of fear. It fears the disruptiveness and discontinuity of radicalism. Where the radical would smash the existing shell and substitute another, the progressive would rebuild the existing shell piecemeal, and in this process of gradual reconstruction remodel its form and content.

The progressive holds, in other words, that however rapidly human advance may be accelerated by innovative initiative and rational direction, it must nevertheless be evolutionary and continuous. The future must grow out of the present, as the present has come from the past, by a "natural," orderly process of development, not through those sudden jumps and changes of direction, those "discontinuous variations," to borrow a biological term, which constitute social revolutions.

Progressivism is, of course, vigorously if not bitterly opposed to reactionism, but it is almost as bitterly opposed to extreme radicalism, as, indeed, moderate radicalism is frequently also. While advanced progressivism can hardly be distinguished from mild or moderate radicalism, we may say that in general the progressive is averse to radicalism because he shares with the conservative a strong sense of order, a high valuation of past experience and a firm conviction in the stability and unchangeableness of human nature. Moreover, where special interests, economic or otherwise, are at stake, the progressive, like the conservative, may fear the results of radical change upon the interests of himself and his class.

Liberalism in a general sense is practically synonymous with progressivism, though the term may connote a slightly less aggressive attitude than is commonly associated with progressivism.

More specifically, current usage applies the term liberal to those who, though they break with conservatism and hold reactionism in contempt, still hold that the main contours of our present political, economic and social life are, if not ideal, at least better than anything to be looked for through revolution or the quick transformations demanded by the radical. The liberal may hold, speculatively, that in ultimate ideal our present mode of life and social organization will be regarded by the peoples of the distant future to be as crude, inefficient and inhuman as we now regard the life of our wholly barbarous forebears; and yet he will reject radical reform or revolution on technological and especially on psychological grounds. His attitude, and there is much to be said for it, both from the standpoint of scientific psychology and from any rationalist's observation of human nature in everyday life, is summarized

in the sentiment: "Yes, all that would be very good and attractive if human nature were different, but it isn't." When it comes to the extreme speculative idealism of a humanistic philosophical anarchist like Bertrand Russell, that is the inevitable sentiment of all, from reactionary to socialistic radical—and doubtless of Mr. Russell himself.

In a still narrower sense, the liberal of to-day, like the economic and political liberals of England and France of the nineteenth century, is one who regards free competition, private initiative and political government as crystallized in the English or American system as approximately ideal. He is naturally averse to reforms leading to government ownership or to socialism and to more government control than is essential to that somewhat traditional and elusive thing, free competition.[2]

The more a term is on everybody's lips the harder it is to define it. This is particularly true of the word "radicalism." Etymology, as usual, gives us little help. The dictionary definitions are figurative and hazy. About all they tell us is that "radical" and "radicalism" carry the double connotation of change and thoroughness. But so may "reactionism." Radicalism and reactionism merely idealize and advocate change in diametrically opposite directions, the one towards the old, the other towards the new. Radicalism means innovation; reactionism suggests literally renovation, a bringing back and renewing of the old.

We may define radicalism as the desire for, and the advocacy of, speedy, deep and thoroughgoing innovative reform or revolution, either touching only certain aspects of social relations and processes or involving the whole social order.

As both social evolution and social revolution have, on the whole, during the modern period, been toward political and social democracy and away from absolutism, authoritarianism and class privilege, radicalism has been, is at present and for a long time will continue to be directed to the project of rapid, accelerated democratization. If applied to a case of extreme economic radicalism like the bolshevist régime in Russia, this statement might be regarded as humorous, in view of the autocratic methods of Lenine and Trotsky. The bolshevist reply is, of course, that these methods are merely a necessary temporary expedient in the service of ultimate democracy. Final proof of the validity or falsity of this excuse lies only in the future.

[2] Perhaps the best brief presentation of this type of liberalism is Woodrow Wilson's "The New Freedom," 1913. Contrast, for example, M. P. Follett's "The New State," 1920. Bryce's "Modern Democracies," 2 vols, 1921, is also suggestive.

It should be noted that two radicalisms, both visioning thoroughgoing innovation, may point in different if not opposed directions. Socialism and anarchism, for illustration, agree only in wishing the abolition of the present social system; further than this, they have little in common, for anarchism, very credulous as to the innate goodness and reasonableness of man, would abolish all coercive forms of social control,[3] while socialism, with less childlike faith in human perfectibility and greater practical insight into the difficulties of economic organization, looks forward, generally speaking, to a very material increase in the amount and effectiveness of social control over the actions of the individual. Much the same kind of opposition exists between moderate socialism and communism. In England, in the first third of the nineteenth century, two radicalisms, Cobdenism (free trade, *laissez faire*) and socialism, were similarly opposed, though they were in agreement in demanding the abolition of the traditional Tory mercantilist economic policies[4]

In English politics the term "radical" was originally an opprobrious epithet applied by aristocratic Tory reactionists to a group of liberals who did not regard the Reform Bill of 1832 as the last word in the extension of the parliamentary franchise.

Since the world war there has been a noteworthy, and in some quarters, successful, attempt to revive this opprobrious use of the term. The attempt has been especially general in the United States, where the tendency seems to many liberals to be less toward real democracy than it is in England.

The central social conflict of to-day is without doubt the conflict of economic interests. This struggle is waged along two intersecting planes, one of class, the other of nationalistic interests. In these respective planes the conservative and reactionary positions are held by the capitalistic employing class and the nationalists, while the extreme radical positions are held by those who aim at some form of comprehensive economic collectivism and in general are advocates of internationalism. This alignment is by no means mere accident, but is the historical and the logical result of conflict of the interests involved. Be that as it may, however, capitalistic, corporate reactionism stands in determined defense against the massed attacks of radical collectivist internationalism. Thus it becomes easy to associate "patriotism" and "loyalty" with capitalism and nationalism, while "radicalism" is made to carry the

[3] *Cf.*, for example, Bertrand Russell, "Proposed Roads to Freedom," 1919.

[4] Leslie Stephen, "The English Utilitarians," 1900, Vol. III, p. 38. As to the radical democrats in England from 1830 to 1870, see Bryce, "Modern Democracies," 1921, Vol. II, p. 568.

strong implication of disloyalty (pro-Germanism during the war) and of socialism or "bolshevism." By this process of associative emotionalism, consciously aided and stimulated by a none too scrupulous system of well-financed propaganda, "radicalism" and "bolshevism" have been made to mean to the average business man and to many others practically the same thing, and that something to be dreaded and fought against by every available means.

That this uncritical usage is unfortunate, entirely apart from the respective merits of capitalism and socialism or of nationalism and internationalism, a moment's reflection will show. In the first place such usage is the result of combative emotionalism and intolerance, and these sentiments rarely if ever advance the cause either of truth or of human welfare. In the second place such a narrowing of the connotation of the term radical deprives it of significance outside the field of the economic and political struggles and leaves us without a term to denote the thoroughgoing innovative attitude in other phases of human life, for example, in religion, ethics and art.

A still weightier reason against this popular usage is that by no means all the individuals who advocate really radical measures, that is, thoroughgoing innovation in some particular field of human activity, even in the economic, are socialists, or internationalists, much less communists or bolshevists. We should hardly withhold the term radical from the staunch single-taxer, from the advocates of the abolition of the United States Senate or the Supreme Court, or those who would initiate a wide-reaching system of governmental price regulation, divorce by mutual consent, or compulsory education of every normal boy and girl to the age of eighteen. Each of these is (or would be) but a limited radicalism, that is radicalism applicable to only a single part or phase of our social organization, but within the scope of its interest, attention and design each is just as truly radical as is socialism or internationalism. It can hardly be said that the Eighteenth Amendment and the Volstead Act were not radical innovations. Curiously enough, however, popular usage has not taken to calling the prohibitionists socialists.

There is, then, in every field of human sentiment, thought and action a continuous gradation of attitude from reactionism to radicalism. The terms conservatism and radicalism should always be regarded as relative, both to each other and to the standards of valuation or sentiment current at the time. What appears to one person or at a given time or in a given place extreme radicalism may be to another person in another time or place hidebound conservatism. As there are degrees of conservatism, so there are gradations in radicalism. Comprehensive radicalism is revolution-

ary in thought and purpose. In method it may be either revolutionary or reformist. Less comprehensive or thoroughgoing radicalism may be reformist (as distinguished from revolutionary) in both aim and method. In general, history shows fairly well that the radicalism of to-day becomes the liberalism and progressivism of to-morrow and the conservatism of the day after. When the aims of the radicals of a particular epoch are accomplished they usually become conservatives. But however rapidly sentiments and standards of valuation may shift, the radicalism at any time existent is always an attitude which demands thoroughgoing change through conscious innovation.

It may be suggested that a distinction should be made between radical desires and innovative impulses, since in the absence of such distinction all innovators, inventors like Edison or Bell or Westinghouse, all creators of new architectural styles, all those who introduce new models in art or literature, would have to be classified as radicals. It might be convenient to think of thoroughgoing innovation as radical only when advocated or carried out against opposition. Radicalism would then be defined as desire for thoroughgoing innovation opposed by conservative objection and obstruction. While this distinction is logical enough, it has more academic than practical significance.

Distinction between thought or theory and action should be kept in mind—a distinction somewhat more significant in radicalism than in conservatism. Conservative sentiment and conservative conduct may coincide without excessive expenditure of energy. On the other hand, radical sentiment or theory may not result in radical action, because such action means not only doing something but doing it against the whole weight of conservative inertia if not against the violent opposition of interested reactionism. Moreover, radicalism is in a sense a less "natural" attitude than conservatism, because the radical not only has to meet the pressure of conservative inertia and reactionary opposition of other persons but also to overcome the conservative tendencies of his own nature.

Returning to the other end of the attitudinal spectrum, we find that some conservatism is the expression of sincere and relatively unselfish intellectual conviction; that most is the product of mere habit and uncritical fear, and that not a little of it is thoroughly selfish in its motivation and insincere in its expression and reasoning. So far as conservatism is the product of conscious motivation, two primary motives prompt it: the one is selfish, material interest, economic or otherwise, in the established order of things; the other is a temperamental attachment to things-as-they-are. The attachment may or may not be productive of good or logically jus-

tifiable, but the individual always finds, if forced to, what seem to him good and sufficient reasons for it, and hence for the essential propriety and rightness of the things—the ideas, beliefs, institutions and relations—to which he is attached. Sometimes his reasoning may have objective scientific validity, but it is quite as likely to be the type of reasoning for self-defence and self-justification which the psychoanalysts call "rationalization," that is, casuistry.

Because of this fundamental difference in motivation it is desirable, in an attempt to analyze the motives and characteristics of the conservative attitude, to distinguish what we may call, for want of better terms, *interested* conservatism and *disinterested* conservatism. Interested conservatism is motivated by narrowly selfish, egotistical, individual or class interests. The interested conservative invariably has an axe to grind, and it is distinctly his own. The motivation of interested conservatism is mainly, but not entirely, economic. Disinterested conservatism, on the other hand, is an attitude due not to the calculating quality of the "narrower selfishness" or of conscious class interest, but rather to the pervasive influence of the instinct of fear, and of association, imitation, habit and adaptation. It is thus both temperamental and characteristic.[5] Both interested and disinterested conservatism may be observed in the same individual, and they gradate into each other in a manner which makes too sharp distinction between them erroneous.

In a very fundamental psychological and ethical sense, it may be argued that there is no such thing as disinterested conservatism, or, having regard for conscious motivation only, a disinterested attitude of any kind, since we assume those attitudes which correspond to our strongest habits, desires and interests. Any attitude may in this sense be regarded not only as the expression of the nature of the person but as a servant to the functioning of his personality. Whether we have quick and sensitive sympathy or are insensitive and unsympathetic, and whether we are broadly intelligent in finding our own happiness, in conjunction with that of others or are directly, narrowly and unintelligently selfish, it may be maintained (again so far as conscious motivation is concerned) that we always do those things which, under the circumstances present to our appreciation, we deem will give us the most satisfaction.[6] We are

[5] Broadly speaking, psychology calls traits which the individual possesses by reason of organically inherited instincts or tendencies "temperamental"; those which result from environmental influence "characteristic."

[6] No crude hedonism is implied by this statement. It is not assumed that all human motivation or even the major part of it is conscious or that all conscious motivation is intelligent.

not concerned at this point, however, with this broader, deterministic and somewhat unconventional conception of self-interest. Whether all conduct be found in the last analysis to be self-centered or not, the practical fact remains that some people are temperamentally conservative and others so primarily from conscious motives of material self-interest in the narrow sense. And this distinction proves significant and essential to an attempt fairly and objectively to analyze the psychology of conservatism and the influence of conservatism upon social ideals and social achievement.

THE CENTENARY OF A UNIQUE DISCOVERY

By Dr. ARTHUR H. SMITH
YALE UNIVERSITY

In science, as in other activities, it is commonly said that there is nothing new under the sun and that there are definite cycles in the conceptions which have been held in the course of human progress. When one reviews the history of any branch of culture, he sees the reappearance of ideas at longer or shorter intervals alternating with periods in which the same ideas are hopelessly out of date. Surveying the numerous instances which fortify this contention, the apparent validity of the general conception of recurrent "fashions" in scientific thought seems established. However, the very fact that progress has been made in explaining natural phenomena indicates that new information is being added to the sum total of knowledge.

From the point of view of fundamental discoveries, the nineteenth century may be called the Golden Age in the history of natural science. The physiological sciences, especially, were benefited by the effective combination of genius and opportunity during this time. The discoveries of Magendie, Beaumont, Bernard Ludwig, Voit, Pawlow and others form the foundation stones upon which rests the modern superstructure of functional, physical and nutritional physiology. And so it is given to us, in this next century, to celebrate the centenary of many epoch-making discoveries in a variety of fields of endeavor.

The constancy of the reaction of the body fluids represents a fundamental physiological property. And yet, while the blood and tissues maintain their approximate neutrality tenaciously, the cells of the mucous membrane of the stomach produce the gastric juice which is relatively strongly acid. Acidity of such strength occurring in any other place in the body would occasion serious results. It is not strange, then, that the announcement of Prout's discovery of "free" hydrochloric acid in the gastric juice in December, 1823, caused a sensation among the scientific men of his day. In order to appreciate the significance of this striking revelation it is well to trace briefly the development of the ideas of gastric digestion up to the beginning of the nineteenth century.

From their own observations, the ancients knew that digestion

consisted, in principle, of converting solid materials to something soluble, or at least semi-fluid. The physical differences between the food ingested and the wastes excreted were perfectly obvious. What forces residing in the body could bring about such a change? It was natural to impute this power to such mechanisms which were familiar, and thus heat, putrefaction, mechanical abrasion and fermentation were variously held responsible for the process of digestion. Toward the end of the dark ages, under the mystic influence of alchemy, Van Helmont suggested that digestion takes place by means of the energy dispensed by the archeus. Sylvius, writing at the same time, thought that gastric digestion is closely similar to ordinary fermentation, and Grew, somewhat later, considered the whole phenomenon to be nervous in character. Contrasted to these fantastic hypotheses was that of Redi, who looked upon digestion in man as being brought about by mechanical means such as occur in the gizzard of birds. At about this time (1681) Borelli reported significant observations on the solution of bone by the gastric juice. Haller,[1] writing in the middle of the eighteenth century, knew that in the stomach food was "digested in an heat equal to that of incubation, imparted by the contiguous heart, liver and spleen" by the various juices found there which produced solution much as "warm water and time do in other situations." Haller observed that "metals themselves, by long stay in the stomach, grow soft, and are eroded" and also that "the juice in the stomach alone, by a continuance of its action, in fishes, dissolves the bones which they devour."

Although there were these hints at the truth with reference to the *modus operandi* of gastric digestion, it remained for the French naturalist Réaumur to initiate systematic experiments on the gastric juice, the results of which were published in 1752. He observed digestive changes *in vivo,* convinced himself that there was no grinding action in the stomach and finally obtained gastric juice by allowing a tame buzzard to swallow and regurgitate metal tubes containing sponges.

Somewhat later (1783) the work of Réaumur was repeated and extended in a series of masterful researches by the Italian monk Spallanzani. As a result of these studies he was convinced of the powerful digestive action of the fluid in the stomach of animals. In addition, he obtained samples of his own gastric juice and repeated his experiments in glass flasks, where he observed the digestion of meat. Some of this fluid kept in a stoppered flask—"ne changea ni de goût ni d'odeur, quoique je l'aye conservé pendent un mois

[1] Haller: "First Lines of Physiology," First American edition, 1803, p. 317, 318, *et seq.*

trés-chaud de l'été."[2] Spallanzani recognized the antiseptic quality of the gastric juice, but made no suggestions as to the possible cause of it. Both Carminati and Brugnatelli, contemporaries of Spallanzani, had described the acid character of the gastric juice of carnivorous birds. Spallanzani, therefore, requested his colleague Scopoli, a chemist, to analyze some gastric juice. The report sent back stated, among other things, that there were large amounts of ammonium chloride and that with silver nitrate a heavy precipitate was obtained. Scopoli finally concluded that "le sel marin est produit par les forces vitales, & l'on pourroit soupçonner que l'acide marin est un produit des animaux qui habitent la mer."[3] Lacking any convincing evidence to the contrary, Spallanzani therefore concluded that the gastric juice was normally neutral. Thus because of the limitations of chemical methods then available, the discovery of the "free" hydrochloric acid was missed and not until forty years later was definite proof produced of its existence in the gastric juice.

An interesting contribution to the nature of the acid in the gastric juice was made by John R. Young, an American, in a dissertation submitted to the faculty of the University of Pennsylvania in 1803. Dr. Young relied entirely on his own observations for the facts which he disclosed. Experiments *in vivo* and *in vitro* upon bullfrogs and upon human beings convinced him that the digestive action of the gastric juice was not due to fermentation. By the use of litmus paper and indirectly through testing the solvent action on bones, he found that the fluid in the stomach was acid. Since the gastric juice of a fasting frog was acid, he decided that this acidity did not arise from fermentation but was secreted by the stomach. Obtaining a precipitate when lead acetate was added to the filtered fluid, he concluded that the free acid in the gastric juice was phosphoric, since lead phosphate is precipitated from urine by similar procedure. From silver nitrate a precipitate was obtained on adding gastric juice which was considered by Dr. Young as confirming his previous tests. It was thus by a mere turn of fate in the form of inadequate qualitative analysis that the credit for making an important discovery passed from America to England.

Five years after the presentation of Dr. Young's thesis a youth of twenty-three began the study of medicine in Edinburgh. This young man had, for some reason, not suffered the usual course of schooling applied to boys of that day, but had studied at home and, left to his own inclinations, had gathered much useful classical and

[2] Spallanzani: "Experiences sur La Digestion," Lausanne, 1785, p. 263.
[3] *Ibid.*, p. 308.

scientific knowledge. This early method of acquiring information and an inborn instinct for careful observation seem to have influenced the activities of his mature life to a marked extent, for no sooner had William Prout left the hospitals in London and "set up" in business for himself in the Strand than he began to publish the results of investigations on a wide variety of medical and chemical subjects. He spent considerable time studying the quantity of carbon dioxide emitted from the lungs under various conditions. The chemistry of the urine and amniotic fluid then claimed his attention. He supported Dalton's atomic hypothesis and suggested that all elements were composed of hydrogen atoms. In both 1819 and 1820 he published papers on the nature of urinary calculi and the treatment for gravel. For the next two or three years he busied himself with observing the changes in composition of the egg during incubation. In December of 1823, before the Royal Society, Prout produced his experimental evidence showing that in the gastric juice "the acid in question is the muriatic acid and that the salts usually met with in the stomach are the alkaline muriates."[4]

In order to determine the relative quantities of the various chlorides he proceeded as follows: The stomach of a rabbit killed at the height of digestion was thoroughly extracted with water until nothing more was dissolved. The extract, "which always exhibited strong and decided marks of acidity," was allowed to settle and the clear supernatant fluid divided into four parts. One part was evaporated to dryness and ignited and the chlorides determined in the ash. This was the chloride in combination with fixed alkali. The second part was saturated with potash, ashed and the chlorides determined. This indicated the total amount of hydrochloric acid present. The third part was titrated with potash and the free acidity determined. By adding this to the chloride in combination with fixed alkali and subtracting from the total chlorides, the chloride present as ammonium chloride was measured. Finally, when he failed to obtain a precipitate when barium chloride alone or when ammonia was added he concluded that neither free sulfuric nor free phosphoric acid was present. Using the above procedure, Prout identified free hydrochloric acid in the gastric juice of the dog, horse, calf, hare and man.

The chemical sense and clear line of reasoning which Prout showed in making his experiments were sound, and history has proved that his deductions were correct. Later, Prout concluded that the source of the hydrochloric acid lay in the chlorides of the blood, from which the Cl-(ion) is separated by vital or electrical action and passes into the stomach. Save for some new words

[4] Prout: *Philosophical Trans.*, 1824, p. 45, *et seq.*

given us by Arrhenius, how much farther have we advanced in these past hundred years in explaining the mechanism of formation of hydrochloric acid in the stomach?

In 1826 appeared the account of the classic work of Tiedemann and Gmelin. These authors in substantiating the work of Prout remark:

> Prout gebühret die Ehre der ersten Entdeckung. Aber wir haben sie ebenfalls unabhängig von ihm, in Februar 1824 bei der Distillation verschiedener Magenflussigkeiten entdeckt, und erst einen Monat nachher kam uns seine Abhandlung über diesen Gegenstand zu Gesicht.[5]

Tiedemann and Gmelin, in addition to finding free hydrochloric acid, claimed to have found free acetic and butyric acids. In 1825 Leuret and Lassaigne, successful competitors of Tiedemann and Gmelin for the prize of the Académie Française, claimed to have found only lactic acid and looked upon Prout's discovery with suspicion. According to them, his chloride determinations were incorrectly done and "Les conclusions du travail de ce chimiste sont donc inexactes."[6]

While on the continent there were partial corroborations by some investigators on the one hand and actual contradictions on the other hand there appeared in 1833 the account of a remarkable series of observations which offered convincing support to Prout's work. In that year Dr. William Beaumont, an American army surgeon, published the results of his experiments on Alexis St. Martin, the now-famous "versuchstier" whom fate had placed in Beaumont's hands while the latter was stationed at an army post in the wilds of upper Michigan in 1822. No part of the phenomenon of gastric digestion was overlooked by this keen observer and it is with interest that we search for his first-hand information on the acid of the gastric juice. In the second series under Experiment 11 appears the following:

> Dec. 14 (1829). At 10 o'clock, P. M., after eighteen hours fasting, introduced tube, and drew off one and one half ounces of gastric juice. It was clear, and almost transparent; tasted a little saltish and acid, when applied to the tongue, similar to thin mucilage of gum arabic, slightly acidulated with muriatic acid. . . .[7]

Beaumont later sent some of the gastric fluid to his friend Professor Dunglison, at the University of Virginia, who examined it

[5] Tiedemann and Gmelin: "Die Verdauung nach Versuchen." (Vol. I, preface p. XII.)

[6] Leuret and Lassaigne: "Récherches Physiologiques et Chimiques pour servir a L'Histoire de la Digestion," Paris, 1825, p. 117.

[7] Beaumont: "The Physiology of Digestion," Second Ed., Burlington, 1847, p. 129.

with the aid of Professor Emmett. These men reported finding free hydrochloric and acetic acids. On distilling, free acid passed over and "the quantity of Chloride of Silver thrown down on the addition of the Nitrate of Silver was astonishing."[8] Thus, some of the most substantial support for Prout's work came from early American investigators.

In 1835, Braconnot, a French chemist, showed that in the alcoholic extract of the fat-free gastric juice he obtained not crystalline zinc lactate but deliquescent zinc chloride, when zinc oxide was added. In spite of these and still other investigations showing that the gastric juice contained "free" hydrochloric acid, opinion was divided and a group of prominent scientists maintained that it was lactic acid which occurred free in the stomach and that the hydrochloric acid was formed from the interaction of the organic acid on the chlorides during the course of the distillation.

In 1852, two years after the death of Prout, appeared the classic monograph of Bidder and Schmidt dealing with the digestive juices and metabolism. In the section on gastric juice appears the following:

> Als Resultat von 18 ubereinstimmenden Analysen ergab sich, dass reiner Magensaft seit 18—20 Stunden nuchterner Fleischfresser nur freie Chlorwasserstoffsäure, und keine Spur von Milchsaure oder anderern organischen Säuren —der Magensaft von Pflanzenfressern neben freie Chlorwasserstoffsäure noch kleine Quantitäten Milchsaure enthält, die indess nur von den stärkemehlreichen Nahrungsmitteln abzuleiten waren. Die Menge letzterer Säure war daher sehr wechselnd, wahrend die der ersten constant erschien.[9]

Furthermore, they state that the hydrochloric acid is produced by the glandular cells in gastric mucosa, thus settling the dispute as to its origin.

The clear-cut procedure of their analyses and the definite statement of their results seem to have united the divided opinions as to the nature of the acidity of the gastric juice. Indeed, our present-day ideas concerning this one point are very little different from those promulgated by these authors. With the work of Bidder and Schmidt the story of the discovery and identification of the hydrochloric acid in the gastric juice may be concluded. While both Prout and Tiedemann and Gmelin detected the "free" hydrochloric acid independently, the fact that the former published his results two years before that of the latter investigators appeared entitles Prout to the honor of the discovery.

Although Prout's claim to fame rests primarily upon his inves-

[8] *Ibid.*, p. 74.

[9] Bidder and Schmidt: "Die Verdauungssaefte und der Stoffwechsel," Leipsic, 1852, p. 44.

tigations in physiological chemistry, he is also remembered for his directive influence in the science of nutrition. In 1834 appeared the eighth Bridgewater Treatise, entitled "Chemistry, Meteorology and the Functions of Digestion considered with Reference to Natural Theology." In this book are stated Prout's views on nutrition. It is natural and proper, he says, for the higher animals to feed upon those lower down in the scale of life. Man, therefore, has as his legitimate source of food all the organisms of creation. Three kinds of foodstuffs are thus ready made for the use of the human animal; namely, the saccharine, the oily and the albuminous. "Such are the three great staminal principles from which all organized bodies are essentially constituted." "Hence, it not only follows, as before observed, that in the more perfect animals, all the antecedent labour of preparing these compounds de novo, is avoided; *but that a diet to be complete, must contain more or less of all the three staminal principles.*"[10]

This is one of the first expressions of the appreciation of the necessity of fat, carbohydrate and protein in the diet, a fact which entitles Prout to a place among the founders of the science of nutrition. Prout's theory that all atoms are composed of hydrogen atoms attracted considerable attention not only during his life but also afterward and has stimulated much of the accurate work that has since been done on atomic weights.

Not only is it unusual to find a person interested in a variety of subjects such as Prout was, but rarely has one man made such important contributions in three fields of scientific endeavor. The earlier students too often allowed their observations to be colored by the prevalent habits of thought, with the consequence that the light of the truth was hidden under the bushel of superstition and religion. Prout's openness of mind enabled him to conceive the idea and his manipulative skill allowed him to put it to experimental test.

[10] Prout: Eighth Bridgewater Treatise, Second Ed., London, 1834, p. 479, 480.

A SURVEY OF MATHEMATICS AND ASTRONOMY[1]

By Professor E. D. ROE, Jr.
SYRACUSE UNIVERSITY

Introduction

A survey of mathematics and astronomy under the limitations prescribed for this course will permit of only a few general observations concerning the nature, character and contrasts of the two subjects and of their content and human value.

Mathematics is divided into pure and applied mathematics. Pure mathematics is a science of reason and pure reasoning. Applied mathematics receives its facts from observation of the outer universe. It takes or assumes these data

Astronomy is a physical science Observation is the first step in a physical science. Interpretation of the observation is the second step. This second step is of a speculative character because it is not observation of facts. It is the mind's reaction. It is what the mind puts into the observation. It is, therefore, of a speculative or metaphysical nature. A large part of what is called "science" is speculation or metaphysics. If the facts have been well observed according to approved methods which assure their correctness, they may be accepted as tolerably certain.

Speculations or interpretations of facts observed, being the activity of the mind upon the facts, and not facts of observation, possess varying degrees of probability, never absolute certainty. They should always be accepted, if at all, with mental reservations. This is in contrast with pure mathematics.

Pure Mathematics

Pure mathematics is a system of ideas created by reason according to the necessary laws of thought, on the occasion of experience. That is, the mind, by its own activity or spontaneity, and by its own laws, builds up, on the occasion of experience, a system of logically necessarily connected ideas. Absolute certainty is attained in the results. Pure mathematics creates its own objects.

[1] A forty-minute lecture delivered April 23, 1923, before the convocation of the freshman class of Syracuse University in a survey course on fields of knowledge and study.

It does not observe them. This explains the difference in certainty between pure mathematics and astronomy. The former creates its objects, on the occasion of experience, and logically develops the consequences from those objects of its own creation. Experience does not hand over to it its notions of space, for example, although it is experience which first or at some time incites it to act. That the sum of the three interior angles of a plane triangle in a Euclidean space is equal to two right angles is something we do not establish from experience. We have created the concept of triangle. We deduce from this by logical steps the universal result. No plane Euclidean triangle can arise in the future to contradict the result because in the intellectual act we have been able to construct all possible plane Euclidean triangles.

In astronomy it is not so. The mind acts or rather reacts on facts, it is true, but it did not create them. We did not create the objective universe. If we had we would know it with equal certainty. All we have of it is a few facts handed over to us by experience. Our positive knowledge extends only to the cases we have observed. The facts themselves are incomplete.

Pure mathematics is a subjective universe of our own ideal fashioning, and we have it and can develop it as far as we please with certainty, because it is our own creation within ourselves and developed according to the necessary laws of thought. It is an ideal world. God created the outer objective universe. Man created, on the occasion of experience, by the spontaneity or initiative of his own mind, the inner subjective universe of pure mathematics.

While doubtless man's earliest mathematical activity was in his practical intercourse, yet as leisure afforded he began to create this ideal universe within himself. Certain it is that leisure is a necessary condition for the development of mathematical thought. The bombardment of sensations from without must be arrested by strongholds and impregnable fortifications erected by the will in order to protect and shield the mind from the missiles of experience. In contrast, in astronomy, the more missiles of experience the better. In fact observation is its life.

In its development mathematics to-day has gone far beyond the so-called "traditional mathematics," so far, in fact, that the "traditional mathematics," while not overthrown, is so limited and special a portion of the vast field that it can not be taken as the representative of mathematics. A definition of mathematics as it is conceived to-day would be something like this: Mathematics is the science which from given premises draws necessary conclusions. Algebra—which includes arithmetic as a special case—might be defined somewhat in this way: Algebra is the science of the com-

bination of symbols according to previously prescribed laws of combination. Different prescriptions for the laws of combination differentiate the various kinds of algebras from each other. These laws are to-day put at the beginning of each kind of algebra in the form of a set of independent, non-redundant and minimal number of so-called postulates which the symbols must obey in that field in their combinations with each other and which completely characterize and set off that algebraic field from every other one; in other words, completely define the particular field.

Geometry is the science of space and spatial relations. It treats of geometrical forms and their properties. As in the case of algebra, there are various geometries to-day, treating of the different mathematical spaces which the mind of man has created, sometimes grouped under the single generical names of pangeometry, metageometry, etc., comprising such spaces as Euclidean, non-Euclidean, under the forms of parabolic, hyperbolic and elliptic spaces, hyperspaces, space of n dimensions, an Einstein space for use with the theory of relativity, which is simply and easily defined by a system of ten differential equations which must be satisfied in this space, to work with which one must be familiar with the theory of differential invariants and the calculus of variations. In the traditional geometry there are two kinds—a metrical geometry, known as analytic geometry, in which algebraic symbols receive a certain geometrical meaning by convention and algebraic operations are conducted with the symbols and the algebraic results are interpreted geometrically, and a non-metrical geometry, variously known as pure geometry, synthetic geometry, projective geometry, geometry of position, etc., in which no algebra or algebraic calculations but only geometrical intuition and logic are used.

Many and various disciplines have arisen and will still arise unknown and undreamed-of by the old traditional mathematics.

To go farther into the causes of the certainty and universality of mathematics: First, there are definitions. A definition merely states what the thing is, separates it from everything else. It is simple and clear. All terms in it are commonly understood or else have been previously defined. It contains no property of the thing defined. It is what Kant called an analytic judgment. Nothing is affirmed in the predicate that is not logically equivalent with the subject. It is a convertible proposition. Otherwise stated it is an identity. Its form is, A is B. It is sometimes put as B is A, or B is that which is called A. The first form, A is B, in which A is the thing to be defined, is by all means to be preferred. Next come axioms or postulates special to the field. Next, exact logic is used at every step. The method of pure mathematics, with the excep-

tion of necessary syntheses, is in the main deductive. That is, the logical consequences or implications of the thing defined are developed, in a chain of logically and necessarily connected ideas, the final idea necessarily following from the premises.

Aside from its logic, its necessity, certainty and universality, mathematics owes its superior power to its symbolic language, the most powerful language known. It made no great progress until symbolic language was employed. This language enables it to outstrip every other science. An example of this follows: A determinant of the 16^{th} order would as a determinant if printed in large figures occupy two thirds of a page. If written out in the ordinary algebraic manner in full, and printed in volumes of 200 pages each, it would require just 4,358,914,560 volumes to contain it. And if libraries four to a block (two on each side of an avenue to a block) and eight blocks to a mile, and each library to hold a million volumes, were built, this determinant avenue would be a little over 136 miles long. It is evident that it could not be read through even once in a lifetime. But as a determinant it can be handled, used and operated upon without difficulty. Thus, by this powerful language one has possession in this single instance (and it is only one such) of all the million volume libraries double lining an avenue over 136 miles long. The necessity, certainty and universality of pure mathematics afford a perfect intellectual satisfaction not experienced in any other field of science.

As to the applications of mathematics we may mention commerce, all business, physics, chemistry, astronomy, biology, psychology, political economy, logic and numerous other fields. In fact, the universe is, in one of its aspects, a mathematical universe. Therefore, this aspect of it can not be reached by the student without the mastery of considerable mathematics. Whoever wishes to go to the bottom of astronomy, physics, chemistry and other fields must be equipped with mathematical tools for penetrating study and investigation. And mathematics in its turn owes much to the stimulus which it has received from these sciences in their demands upon it for farther developments for the solution of their problems.

Architecture and engineering structures call for more or less mathematics. Ships, railroads, steam engines, electric motors, all the machinery of industry, rest ultimately on mathematics. Every science strives to reach the ideal of mathematics. Until it does this to some reasonable degree, it is not yet an exact science, a characteristic of which is ability to predict the future with mathematical exactness within the limits of the errors of observation.

Then mathematics finds an application in its ability for training the mind. It is not perhaps for every one; but for him who

will take it there is no finer training. In England, many of those who are going into the ministry and law quite regularly take all the mathematics they can at the University of Cambridge. The reason for its superiority for training is that it is a pure logic. You can see the mind working according to its necessary laws of thought, that is, you can see the machine running light so far as being cumbered down or cluttered up with objects or matter is concerned. You have a chance to study the machine itself as it runs without material things obscuring the view. Mathematics has also a moral aspect. One knows in it whether he is right or not. He can not deceive himself without knowing the deception. It naturally trains one to honesty, moral probity, straightness and habits of exactness.

Mathematics also exercises the emotion of the esthetic and the beautiful. But this is not for the tyro who takes a course in required mathematics under compulsion and chafes under the exacting discipline of its technique His prejudice against it blinds him to any of its excellencies. When the technique is so mastered as to become second nature and it no longer irritates, one can appreciate and enjoy the beauty of its truths. In fact, it offers the highest type of intellectual beauty and pleasure.

Mathematics affords one of the best means of training in the art of exact speech. Abraham Lincoln and his immortal Gettysburg speech afford an example of this. When asked by a professor of rhetoric at the close of his speech how he could have trained himself to produce such a masterpiece, Lincoln, without admitting that it was a masterpiece, modestly said that he was accustomed to spend a few minutes each day in reading over propositions in Euclid's Elements of Geometry, a work in which the language is very fine.

Sylvester, a great mathematician, claimed that poetry and mathematics come together in their higher flights. This is doubtless true in their higher flights, but not in their incipient stages, by which both unfortunately are quite sure to be judged by those who properly know nothing of either. As well judge poetry in the incipient stage of mere doggerel or catterel or music in the stage of finger and voice exercises, as to judge mathematics in the stage of mere acquirement and practice of its technique. Of course such judgment has no ultimate value. And there is no question that mathematics and philosophy come together. Royce expected great benefit to philosophy from modern mathematical developments.

Those who decry mathematics as training are people who advertise that they could not handle it or have not advanced far enough to know what they are talking about. Of course one may have a deficiency of mathematical ability and appreciation and still have other ability. One may live with only one lung or one hand or

minus some other organ of the body. He simply deserves our tenderest sympathy. You would not think he would get up on the house top and proclaim this deficiency with pride, and decry the uselessness of having a perfect organism. Yet there are those who do this and thus expose themselves every time they speak and write against the value of mathematical training. It reminds one of the fable of the fox who lost his tail. Being caught by the tail in a trap, he was obliged to come away without his tail, in order to free himself. At the next convocation of the foxes he arose and decried the value of tails. He said he had never realized how useless they were until he lost his. He moved that they all have their useless tails amputated. The proposition received only one vote. His audience were foxes, also. What has been said here of those who decry mathematical training could be said equally well of those who decry the value of any other training subject.

Astronomy

Astronomy is the science which studies and investigates the outer and objective universe, sometimes called the macrocosm. It is a physical science of observation or an observational science. Therefore, besides the facts observed, it contains a mass of speculations, of varying degrees of probability. Some of its speculations are pretty good investments. Others may or may not turn out so well.

There is a pseudo-science, that is, a sometimes so-called science, which is not science at all, but superstition, humbuggery, fraud, a scheme to take in and fleece the unwary man and the human sucker, which goes by the name of astrology. Don't confuse this with astronomy. Astronomy proceeds by the scientific method, astrology by occult methods which are not open to scientific scrutiny.

Astronomy is one of the oldest of the sciences. The earliest interpretation of the diurnal motion of the stars was that the earth is the center about which all the heavenly bodies revolve. This is the geocentric theory. It was taught by Pythagoras in connection with crystal spheres containing the stars and the planets, the spheres producing the music of the spheres. It is, however, claimed by some that Pythagoras only held this view as an exoteric doctrine for the *hoi polloi*, the common people, and taught the heliocentric theory or sun as the center as an esoteric doctrine for the initiated. Aristarchus held the heliocentric view. Ptolemy reverted to the geocentric theory, and supported it so ably that it lasted several hundred years until Copernicus reinstated the heliocentric idea.

Since Copernicus it has remained as the accepted interpretation of the solar system. However, it has been retouched and precised. Kepler replaced the circles of Copernicus by ellipses as being the orbits of the planets. Newton added the law of gravitation, Einstein proposes the introduction of relativity and farther refinement of gravitational doctrine.

And now the earth, instead of being the center of the universe, has become reduced to a mere celestial bee, buzzing at the rate of 18 miles per second around the sun in the sunlight, while the sun, the king bee carrying along with him his swarm of celestial bees, and formerly the central system of the universe, is buzzing off, at the rate of 12 miles per second, towards a point in the constellation of Hercules.

The problem of astronomy is overwhelmingly vast. As it is a physical science we can not attain certainty, but as the pendulum of speculative interpretation swings back and forth probability of advance increases with the time. It is now quite probable that the solar system consists of the sun, whose distance from the earth and whose mass are known within small limits, no intramercurial planets, Mercury, Venus, the Earth and the Moon, Mars with two moons, about a thousand asteroids or smaller planets, Jupiter the giant planet with nine moons, Saturn with his gorgeous rings and ten moons, Uranus with four moons, Neptune with one moon, a possible transneptunian planet, many comets and several meteor swarms, and the zodiacal light. All these bodies are so well known that the movements of the major ones among them can be predicted with great accuracy for years in advance. Then, besides our solar system there are other solar systems innumerable which form the starry host of heaven, double and multiple stars, clusters, nebulae, both bright and dark, spiral nebulae, possibly island universes, and countless worlds and systems.

Since pure mathematics is our own creation, we are in possession of and may begin with the general and descend to the particular in its domain. On the contrary, since astronomy is a science of observation and can not, like pure mathematics, be created by the spontaneous action of the mind according to the laws of thought, without observations, we must begin with the particular and work up to the general, if we can. We must make the attack on particulars at specific points where there seems to be some chance of success, and hence double stars, nebulae, clusters, Magellanic clouds, proper motions, parallax and star drifts, giant and dwarf stars, stellar temperatures and stellar evolution are for us the portals of the temple of the universe.

Why should one spend time on so vast a problem, in which

years, yes, centuries, of observation are necessary to make some slight advance? So that one may not live even to see the fruits of his labors. Truly astronomy is not a bread-winning occupation. What is it for? I believe that "man does not live by bread alone but by every word that proceedeth out of the mouth of God," in nature as well as in revelation. An old catechism reads something like this: "What is the chief end of man?" Answer: "To know God, to love him and enjoy him forever." I believe that astronomy is for the development and expansion of the soul, that it can satisfy some of its needs in its attempts and aspirations to grasp the reality and meaning of the universe in which it finds itself. To attempt to solve the riddle of the universe is to attempt, feebly though it may be, to understand something of the intelligence, plan, and purpose of the Creator as manifested in his creation, to think his thoughts after him in the starry firmament on high, as well as in the minutest organism which exists. Said Kant, as translated by Sir William Hamilton: "Two things there are, which, the oftener and more steadfastly we consider them, fill the mind with an ever new and rising reverence—the starry heaven above, the moral law within." David said: "The heavens declare the glory of God and the firmament showeth his handiwork." And St. Paul: "The invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead." Dr. Townsend, of Boston University, a theologian and amateur astronomer, maintains that the sun, planets and stars were created for our instruction, profit and pleasure. Whether this is true or not, we may derive instruction, profit and pleasure from them. Poincaré, one of the greatest of modern mathematicians, said: "Astronomy is useful because it raises us above ourselves; it is useful because it is grand; that is what we should say. It shows us how small is man's body, how great his mind, since his intelligence can grasp the whole of this dazzling immensity, where his body is only an obscure point, and enjoy its silent harmony. Thus we attain the consciousness of our power, and this is something which can not cost us too dear, since this consciousness makes us mightier." Says the Book of Genesis: "In the beginning God created the heaven and the earth." God placed man on the earth with the command to subdue and conquer it. And the other sciences are engaged in the conquest of the earth, while astronomy is engaged in the conquest of the skies.

Who could picture the loss to the intellectual development of the world if the stars had been forever shut out from our view by an impenetrable veil of cloud surrounding the earth? Who could estimate the loss to exact science? For while astronomy itself is not

primarily for gain, the nature of its problems, demanding the highest exactitude in investigation, has inspired other sciences and has developed instruments of precision which other sciences have found exactly suited to their needs, and from whose use wealth has resulted in application of science. The story of the mutual stimulus and advantage which astronomy and mathematics have afforded each other, and one of the brightest and most important in the pages of science, is too long to recount here.

Time does not allow a detailed survey of recent and interesting astronomical speculations, regarding star drifts and the two supposed streams of stars, giant and dwarf stars, the treatment of the stars by mathematical representation similar to that used in the kinetic theory of gases, island universes, the order of the evolution of the stars according to spectral type, and the dimensions of the universe.

I have not mentioned in the first place navigation, the laying out of meridians, terrestrial surveys, the ability to find one's way in a desert, the determination of time, standard time, even the determination of an astronomical scale, obtained first by astronomical observations conducted on the earth, for the measurement of the universe, since these, though most useful, are not the highest benefits conferred on man by astronomy.

A survey of the field of astronomy would be incomplete without mention of astronomical instruments. All, so far as optics is concerned, are based on the utilization and development of the laws of reflection and refraction of light and some other laws of physics. There are the telescope, two kinds, refracting and reflecting, in various forms, meridian and zenith transits, the spectroscope, several varieties, the photometer, various forms, the micrometer, the interferometer, photography and measuring machines. While it would be interesting to give detailed descriptions of these, time does not allow.

Summary

Summarizing: I have tried to explain the difference in character between pure mathematics and astronomy. In the former, we create ideally, on the occasion of experience, and according to the necessary laws of thought, the pure mathematical universe. We have in our intellectual possession and potential grasp all the possible cases. Definitions are clear, postulates mutually independent, logic exact, and to carry out its ideal it has at its command a symbolic language whose power is unlimited. Therefore, we know with a certainty, a necessity and a universality of conviction and therefore with a perfect intellectual satisfaction that belongs to no

other field of science, not even astronomy. For, in the latter we do not create, but have to observe what God has created. Our observation covers only a finite number of cases, and we have not the remaining infinity of unobserved cases in our intellectual possession, hence are not absolutely positive, though by an assumption of the uniformity of nature's laws, which is assumption, and only an object of belief, we expect the infinity of unobserved remaining cases to follow what we assume is the law, which is a considerable expectation, and it must be admitted that astronomy has contributed on the grandest scale to our belief in and expectation of a reign of law in the universe. But this expectation, as a fact, requires confirmatory observation for each extension. Thus the so-called law of gravitation, once accepted for the solar system, was not positively extended to other parts of the universe, until by confirmatory observations on the orbits of binary stars, it appeared to hold. But now to-day this so-called law is in question as to its being the exact interpretation of the observation. Still, it is believed that the ever-oscillating pendulum of speculative interpretation is approaching a limit, and that the probable value of the speculation increases with the time, though it will take an infinite time for it to reach the limit. At least we live in hopes that we are approaching the limit with the advance of time.

We have shown that mathematics is required by every exact science, that it furnishes the ideal and goal of every science which aims to be exact, and that its applications are myriad in fields of human endeavor. We have cited its availability for training, its relation to the moral and the beautiful, to poetry and philosophy.

We have shown that astronomy has as goal a knowledge of the Creator in one aspect of the beauty and grandeur of the universal reality and its meaning, that without the stars we should never have sensed this aspect at all, that it makes us modest on the one hand by showing us our infinitesimal proportions, and on the other hand elevates and inspires us by the majesty of the intellectual grasp which it challenges us to believe we can attain. We have shown its stimulating effect on other sciences, and how they have reaped rewards from its developments. And, lastly, we have cited its everyday practical usefulness in human affairs.

THE INTERIOR OF A STAR[1]

By A. S. EDDINGTON, F.R.S., F.R.A.S.
PLUMIAN PROFESSOR OF ASTRONOMY, UNIVERSITY OF CAMBRIDGE

On December 13, 1920, the angular diameter of a star was measured for the first time in history with an apparatus devised by Professor A. A. Michelson Hitherto every star had appeared as a mere point of light, and no test had been able to differentiate it from a geometrical point. But on that eventful evening a 20-ft interferometer constructed at the Mount Wilson Observatory was turned on the star Betelgeuse, and the measurement revealed that this star had a disc 1/20 of a second of arc in diameter—about the size of a halfpenny 50 miles away. The distance of Betelgeuse is known roughly (unfortunately it can not be found so accurately as the distance of many stars), so that we can convert this apparent size into approximate actual size. Betelgeuse is not less than 200 million miles in diameter. The orbit of the earth could be placed entirely inside it.

Historically this achievement should come rather towards the end than at the beginning of my discourse; but I am to occupy your time with a great deal of theory, and so I thought it well to start with one ascertained fact. The stars are not limited to objects of comparatively small bulk like the sun; there are among them individuals truly gigantic in comparison. We can add another step to the astronomical multiplication table—a million earths make one sun; ten million suns make one Betelgeuse.

This is a comparison of volume, not of amount of material. It leaves open the question whether in order to obtain one of these giants we should take the material of ten million suns rolled into one, or whether we should take the material of the sun and inflate it to ten million times its present size. There is no doubt that the latter answer is nearer the truth. Betelgeuse, I admit, contains more matter than the sun (perhaps 50 times as much); but in the main its vast bulk is due to the diffuseness with which this material is spread out. It is a great balloon of low density, much more tenuous than air, whereas in the sun the material is compressed to a density greater than water.

[1] Lecture given before the Royal Institution of Great Britain, February 23, 1923.

Whether the star is one of these balloon-like bodies or whether it is dense like the sun depends on the stage of its life at which we catch it. It is natural to think that the stars gradually condense out of diffuse material, so that they become denser and denser as their life history proceeds. We can now see in the heavens samples of every stage in the development of a star. The majority of those seen with the naked eye are in the early diffuse state; that is not because these young stars are really more numerous, but because their great bulk renders them brighter and more conspicuous. What I shall have to say about the inside of a star refers chiefly to the young diffuse stars—the *giant stars* as they are called. The reason is that we understand much more about the properties of matter when it is in the condition of a perfect gas than when it is condensed; although the difficulties of treating a dense star like the sun are not insuperable, we have naturally made the most progress with the easier problem of giant stars.

We only observe the physical conditions of the surface of a star, and at first it might seem impossible to learn anything about the conditions in the interior. Consider, for example, the question of temperature. The nature of the light received from Betelgeuse teaches us that the temperature is 3,000° C., not an extravagantly high temperature judged even by terrestrial standards. But this refers, of course, to the layer near the surface from which the observed light is coming; it is just the marginal temperature of the furnace, affording no idea of the terrific heat within. I shall not attempt to explain in detail how we manage to calculate the inside temperatures; but I can perhaps show that there is a clue which can be followed up by appropriate mathematical methods.

Elasticity is a well-known property of a gas, familiar to everybody through its practical application in the pneumatic tire. What gives the gas its elasticity or expansive force is its heat—that is to say, the energy of motion of its molecules hastening in all directions and continually tending to spread apart. The greater the heat the greater the expansive force. Now, at any point inside the star a certain condition of balance must be reached; on the one hand we have the weight of all the layers above pressing down and trying to squeeze closer the gas inside; on the other hand we have the elasticity of this inside gas trying to expand and force the upper layers outwards. Since neither one thing nor the other happens, and the star remains practically unchanged for hundreds of years, we must conclude that these two tendencies just balance. At each point the elasticity, and therefore the heat, has to be of the exact amount needed to bear the weight of the layers above. That is the principal clue by which we determine how much heat there must be at various depths inside the star.

The internal temperature depends on the particular star considered, but it is generally from 2 to 20 million degrees at the center. Do not imagine that this is a degree of heat so vast that ordinary conceptions of temperature have broken down. These temperatures are to be taken quite literally. Temperature is a mode of describing the speed of motion of the ultimate particles of the matter. In a mass of helium at ordinary temperatures the average speed of the atoms is rather under 1 mile per second; at 4 million degrees it is 100 miles per second. This is a high speed, but not a speed to feel uncomfortable over Some weeks hence Sir Ernest Rutherford will be lecturing to you about atoms of helium moving at 100,000 miles a second. I can not vie with him. I usually find that my physical colleagues are rather disappointed with our jog-trot atoms in the stars.

We must imagine, then, a typical giant star as a mass of material with average density about that of air swollen to at least a thousand times the bulk of the sun. The atoms of which it consists are rushing in all directions with speeds up to 100 miles a second, continually colliding and changing their courses Each atom is being continually pulled inwards by the gravitation of the whole mass, and as continually boosted out again by collision with atoms below. The energy of this atomic motion constitutes a great store of heat contained in the star; but this is only part of the store. The star contains a store of another kind of heat, ethereal heat, or ether-waves like those which bring to us the sun's heat across 90 million miles of vacant space. These waves also are hastening in all directions inside the star. They are encaged by the material, which prevents them leaking into outer space except at a slow rate. An ether-wave making for freedom is caught and absorbed by an atom, flung out in a new direction, and passed from atom to atom; it may thread the maze for hundreds of years until by accident it finds itself at the star's surface, free now to travel through space indefinitely, or until it ultimately reaches some distant world, and perchance entering the eye of an astronomer makes known to him that a star is shining.

The possession of this double store of heat is a condition which we do not encounter in any of the hot bodies more familiar to us. It is a new phase of matter beyond the reach of laboratory experiment, although happily the theory is so simple that there can not be much uncertainty as to behavior. It is true that a red-hot mass of iron contains a little of this ethereal heat in addition to the heat comprised in the motion of its molecules, but it is less than a billionth part of the whole. Only in the giant star does the ethereal portion rise to importance. A red-hot metal emits ethereal heat,

but it keeps no appreciable store; it converts the material heat into this form as it is required for use. The star rejects this hand-to-mouth method; and although it is continually changing elements of heat from one form to the other it keeps a thousand years' supply always in readiness, and emits its radiation by leaking ethereal heat from the store. In older theories this feature was not realized; it was supposed that convection currents must exist continually bringing up hot matter from the interior to replace the surface-matter which had radiated and cooled. But now it is seen that the difficulty is rather in the other direction—how does the star dam back the store of ether-waves so that they do not escape from it faster than we observe? This change of view has necessitated modifications of the older theories of Lane and others, and has on the whole considerably simplified the problem.

In the hot bodies of the laboratory the heat is almost entirely in the material form, the ethereal portion being insignificant. In the giant stars the heat is divided between the two forms in roughly equal amounts. Can we not imagine a third condition in which this time the heat is almost wholly ethereal, the material portion being insignificant? We can imagine it no doubt, but the interesting, and I believe significant, thing is that we do not find it in nature.

You have heard of the pressure of light—that light actually has mass and weight and momentum, and exerts a minute pressure on any object which obstructs it. A beam of light or ether waves is like a wind, a very minute wind as a rule; but the intense ethereal energy inside the star makes a strong wind. This wind distends the star. It bears to some extent the weight of the layers overhead, leaving less for the elasticity of the gas to bear. That of course has to be taken into account in our calculation of the internal temperatures—making them lower than the older theory supposed. Just as ether and matter share the heat-energy between them, so the ethereal wind and the material elasticity share the burden of supporting the weight of the layers above. We are able to calculate the proportions in which they share it. To a first approximation the same proportion holds throughout nearly the whole interior, and the proportion depends only on the total mass of the star, not on the density or even on the chemical composition of the material. Moreover, in order to make this calculation we do not need any astronomical knowledge; all the constants in the formula have been determined by the physicist in his laboratory. We need to know the average molecular weight of the material, but I shall tell you later how we are able to fix that approximately in spite of not knowing what elements to expect in the star's interior; that happens to be one of the benefits of dealing with very high temperatures.

Let us imagine a physicist on a cloud-bound planet, who has never heard tell of the stars, setting to work to make these calculations for globes of gas of various dimensions. Let him start with a globe containing 10 grms., then 100 grms., 1,000 grms., and so on, so that his nth globe contains 10^n grms. They mount up in size rather rapidly. No. 1 is about the weight of a letter; No. 5, a man; No. 8, an airship; No 10, an ocean liner; after that comparisons are difficult to find. The following table gives part of his results:

No. of Globe	Ethereal Pressure	Material Pressure
30	0.00000016	0.99999984
31	0.000016	0.999984
32	0.0016	0 9984
33	0.106	0.894
34	0.570	0.430
35	0 850	0.150
36	0 951	0.049
37	0.984	0.016
38	0.9951	0.0049
39	0.9984	0.0016
40	0.99951	0 00049

You will see why I omit the rest of the table; it consists of long strings of 0's and 9's. But for the 33rd, 34th and 35th globes the table gets interesting; and then lapses back into 9's and 0's again. Regarded as a tussle between ether and matter to control the situation, the contest is too one-sided to be interesting, except just from Nos. 33 to 35, where something more exciting may be expected.

Now let us draw aside the veil of cloud behind which our physicist has been working, and let him look up into the skies. He will find there a thousand million globes of gas all of mass between the 33rd and 35th globes. The lightest known star comes just below the 33rd globe; the heaviest known star is just beyond the 35th globe. The vast majority are between Nos. 33 and 34, just where the ethereal pressure begins to be an important factor in the situation.

It is a remarkable fact that the matter of the universe has aggregated primarily into units of nearly constant mass. The stars differ from one another in brightness, density, temperature, etc., very widely; but they all contain roughly the same amount of material. With a few exceptions they range from ½ to 5 times the mass of the sun. I think we can no longer be in serious doubt as to the general cause of this, although the details of the explanation may be difficult. Gravitation is the force which condenses matter; it would if unresisted draw more and more matter together; building globes of enormous size. Against this, ethereal pressure is the main disruptive force (doubtless assisted by the centrifugal force of the star's rotation); its function is to prevent the accumulation of large masses. But this resistance, as we see, only begins to be serious

when the mass has already nearly reached the 33rd globe, and if indeed it is efficacious, it will stop the accumulation before the 35th globe is reached, because by then it has practically completely ousted its more passive partner (material pressure). We do not need to know exactly how strong the resistance must be in order to prevent the accumulation, because when once the resistance begins to be appreciable it increases very rapidly, and will very soon reach whatever strength is required. All over the universe the masses of the stars bear witness that the gravitational aggregation proceeded just to the point at which the opposing force was called into play and became too strong for it.

It was shown by Homer Lane in 1870 that as a gaseous star contracts its temperature will rise. Betelgeuse is typical of the first stage when the temperature has risen just far enough for the star to be luminous. It will go on contracting and becoming hotter, its light changing from red to yellow and then to white. But evidently this can not go on indefinitely. When the condensation has proceeded far enough, the material will be too dense to follow the laws of a perfect gas. A different law then begins to take control. The rise of temperature becomes less rapid, is checked, and finally the temperature falls. We can calculate that the greatest temperature is reached at a density of about 1/4th to 1/3rd that of water. The sun is denser than water, so that it has passed the summit, and is in the stage of falling temperature. So long as the temperature is rising, the brightness of the star scarcely changes. It is becoming hotter but smaller. Calculation shows that the increased output of light and heat per square meter of surface and the decreased area of the surface very nearly counteract one another, so that the total output remains fairly steady. But on the downward path the falling temperature and diminishing surface both reduce the light, which falls off rapidly between the successive stages or types which we recognize. That is entirely in accordance with what is observed to happen.

Taking any level of temperature, a star will pass through it twice, once ascending and once descending. In the main we have been in the habit of classifying stars according to their surface temperature, because it is on this that the spectral characteristics of the light, its color and the chemical elements revealed chiefly depend. But that classification mixes together stars from an early ascending stage and from a later descending stage. For example, a star like Betelgeuse, just beginning its career, is put in the same class with a dense red star, which has run its course and reached its second childhood. They are both red stars of low temperature, and that was good enough for the early attempts at classification. Sir

Norman Lockyer always stoutly maintained the existence of the ascending and descending series, but he was almost alone among spectroscopists in this. He did not actually succeed in separating the ascending and descending stars, though sometimes he came very near to the right criterion. We owe to Russell and to Hertzsprung the actual separation. They discovered it not by spectroscopy, but by measuring the absolute brightness of stars; the greater brightness of the ascending stars, due to their large bulk, easily distinguishes them from the descending stars, at any rate in the low temperature groups. At the highest temperatures the two series merge into one another.

The disentangling of the two series and the recognition of the true sequence of stellar evolution is probably the most revolutionary and far-reaching of recent discoveries in stellar physics. It began to oust the older view about 1914. It is worth noticing that it was found from observations coming under the province of the older astronomy, and not what is generally called astrophysics. The data were parallaxes, proper motions, double star orbits, etc. The spectroscopists had been misled as to the order of evolution, and it was left to the rival branch of astronomy to show the way; but they were not to be outdone for long. Adams and Kohlschütter have found an easy spectroscopic method for distinguishing the ascending and descending stars. Although our main purpose this evening is to grope in the interior of a star, perhaps we may emerge at the surface for a moment to consider what is the difference of surface condition of a diffuse and condensed star, respectively, which enables the spectroscope to distinguish between them.

The state of the outermost layers of a star can, it would seem, be influenced by only two factors: (1) the intensity of the stream of radiant energy crossing through them, and (2) the intensity of gravitational attraction holding them to the star. The former is measured by the effective temperature, so that we have the two variable factors, temperature and gravity. The spectrum presumably will vary as the conditions governed by these factors vary. We must not expect to be able to classify the spectra accurately in a single sequence; they can vary in two directions. The ordinary classification depends principally on the temperature factor; we may call this the longitudinal sequence. Adams's new method aims at disentangling the transverse sequence corresponding principally to the gravity factor. We may say that his method is really a way of finding the value of gravity at the surface of a star, although it is not yet possible to put the value into actual numbers. Clearly gravity will be smaller in the diffuse stage than in the dense stage, on account of the greater distance from the center to the surface.

The effect of lowering gravity is to make the density smaller at corresponding temperature. This introduces an important change in the state of the gas, *viz.*, ionization. At moderately high temperatures the atoms begin to lose one or more of their most loosely attached electrons, a process called ionization. Ionization is facilitated by low density, and prevented by high density. The theory of ionization in stellar atmospheres has been chiefly worked out by M. N. Saha, who has arrived at many interesting results. Here we need only remark that the ionized atoms give rise to different spectra, which have long been distinguished from the spectra of the neutral atoms. The lower density in the atmosphere of diffuse stars should strengthen the "enhanced" lines due to ionized atoms, compared with the "arc" lines due to neutral atoms. The difference in general is not very large, but the atoms of certain elements for which the conditions are most critical are specially sensitive to the change of density. This is the criterion which Adams and Kohlschütter found empirically, and it distinguishes quite easily the ascending and descending series. To a limited extent it also distinguishes the larger and smaller stars within the same series.

Although the stars begin to shine on reaching a temperature of about 3000°, and return to this temperature at the close of their luminous existence, they do not all climb the temperature-ladder to the same height. The more massive stars climb higher than the light stars. We can to some extent calculate the height to which they will go, but I am afraid the figures at present are very uncertain, though there is hope of improving them before long. The sun's surface temperature is now about 5900°. I do not think that it ever went higher than 6600°; it had not sufficient mass to go beyond. Sirius, nearly 2½ times as massive as the sun, has climbed to 11,000°, and at the moment is practically at its maximum, having only just turned downward. Still hotter stars, like Rigel, are known, and these must be more massive still. At the other end of the scale a star of mass less than 1/7th of the sun would not be able to reach 3000°, and could scarcely be luminous; but in any case such small masses would be formed very seldom, for the reason explained earlier in this lecture. It is a well-known fact that hot stars on the average are more massive than cool stars. We see that this is accounted for by the smaller stars being weeded out as the temperature-standard is raised.

We have hitherto pictured the inside of a star as a hurly-burly of atoms and ether waves. We must now introduce a third population to join in the dance. There are vast numbers of free electrons —unattached units of negative electricity. More numerous than the atoms, the electrons dash about with a hundred-fold higher

velocity, corresponding to their small mass, which is only 1/1850th of a hydrogen atom. These electrons have come out of the atoms, having broken loose at the high temperature here involved. An atom has been compared to a miniature solar system: a composite central nucleus carrying positive charge corresponds to the sun, and round it revolve in circular and elliptic orbits a number of negative electrons at comparatively large distances, corresponding to the planets. We know the number of satellite electrons for each element: sodium has 11, iron 26, tin 50, uranium 92. Our own solar system, with eight revolving planets, represents an atom of oxygen. The thermodynamical theory, due mainly to Nernst, permits us to calculate roughly how many of these break loose under given conditions of temperature and density; and in a typical star a large proportion of them must have become free.

This condition solves for us our chief difficulty as to the molecular weight of stellar material. We need to know it in order to perform our calculations as to the state of the star; and at first sight it might seem hopeless to arrive at the molecular weight without knowing the elements which constitute the bulk of the material. But suppose first that the temperature is so high that all the satellite electrons have broken away. An atom of sodium will have separated into 12 particles, *viz.*, 11 electrons and 1 mutilated atom; its atomic weight 23 is divided between 12 independent particles, so that the average weight of each is $23/12 = 1.92$ Next take iron; the atomic weight 56 is divided between 27 particles: average 2.07. For tin we have 119 divided by 51: average 2.34. For uranium 238 divided by 93: average 2.56. It scarcely matters what element we take; the average weight of the ultimate particles (which is what we mean by the molecular weight) is always somewhere about 2. If only the stars were a bit hotter than they actually are it would make our task very easy. Unfortunately they are not hot enough to give complete separation, and the actual degree of separation will depend on the temperature of the star, thus introducing a difficult complication. Generally at least half the electrons are detached, and the molecular weight must be taken between 3 and 4. I hope that the theory of this dissociation of electrons will be improved, because at present that is the chief bar to rapid progress with the theory of stellar constitution. It is a great help to know that the molecular weight is between 3 and 4; but we have reached a stage when it is becoming necessary for progress to know it for each star within much closer limits.

We pictured a physicist on a cloud-bound planet who was able from laboratory data to predict how large would be the masses into which the material of the universe must aggregate. Let us now set

him a harder task. We inform him that we have observed these masses of gas, and, choosing one equal, say, to his 34th sphere, we ask him to predict how brightly it will shine. I have already mentioned that the star keeps practically the same brightness so long as it is a perfect gas ascending in temperature, so it should not be necessary to give the physicist any data except the precise mass. To use the same plan as before, we imagine a series of lamps of 10 candle-power, 100 candle-power, 1000 candle-power, and so on; and his task is to pick out which lamp in this series corresponds approximately to the star. I believe that it is now possible for him to perform this task, and to pick out (correctly) the 31st lamp. But for this purpose it is not enough that he should know all about the heat stored in the interior of the star; the brightness of the star depends on the rate at which the ether waves are leaking out, and that introduces a new subject—the obstructive power of the material atoms which dam back the radiant flow.

Another name for this obstructive power is *opacity*. A substance which strongly obstructs the passage of light and heat waves is said to be opaque. The rising temperature towards the center of the star urges the heat to flow outwards to the lower temperature level; the opacity of the material hinders this flow. The struggle between these two factors decides how much light and heat will flow out. We have calculated the internal temperature-distribution, so that we know all about the first factor; if, then, we can observe the outward flow which occurs, that should settle the value of the second factor—the opacity. The outward flow is capable of observation, because it constitutes the heat and light sent to us by the star.

One of the troubles of astronomy is that our information about the stars is so scattered. We know the mass of one star very accurately, but we do not know its absolute brightness; we know the brightness of another, but not its mass; for a third we may have an accurate knowledge of the density, but nothing else. For Sirius, Procyon and α Centauri our knowledge is fairly complete and accurate; but none of these are giant stars in the state of a perfect gas, and they are therefore useless for the present discussion. But within the last year we have been fortunate enough to obtain complete and very accurate information for one of the giant stars, Capella. This is another of the benefits which astronomy has derived from Professor Michelson's interferometer method of observation. The brighter component of Capella (which is a double star) has a mass 4.2 times that of the sun, and a luminosity 160 times greater. We can use these facts to calculate the opacity of Capella in the way I have described; it turns out to be 150 in C.G.S. units. To illustrate the meaning of this, let us enter Capella and find a

region where the density is that of the terrestrial atmosphere we are accustomed to; a slab of this gas only 6 inches thick would form an almost opaque screen. Only 1/20th of the radiant energy falling on one side would get through to the other, the rest being absorbed by the gas.

It seems at first surprising that 6 inches of gas could stop the ether waves so effectually, but we might have anticipated something like this from general physical knowledge. We give different names to ether waves according to their wave-length. The longest are the Hertzian waves used in wireless telegraphy; then come the invisible heat waves, then light waves, then photographic or ultra-violet waves. Beyond these we have X-rays, and finally—the shortest of all—the γ-rays emitted by radioactive substances. Where in this series are we to place the ether waves in the interior of a star? It is solely a question of temperature, and the ether waves at stellar temperatures are those which we call X-rays—more precisely, they are very "soft" X-rays. Now X-rays, and soft X-rays especially, are strongly absorbed by all substances. The opacity which we have found in Capella is of the same order of magnitude as the opacity of terrestrial substances to X-rays measured in the laboratory.

The following table shows a few of the laboratory results compared with the astronomical value for Capella:

Wave-length (A)	Absorption-coefficient (opacity) in			
	Aluminium	Iron	Silver	Capella
0.5	2	14	10	
0.95	11	80	72	
1.1	21	125	86	
1.3	31	205	152	
2.3	136			
10.0				150

We have been performing an investigation of the absorption of X-rays in a star, parallel to investigations on the same subject made in the laboratory. In one respect the physicist has a big advantage because he can vary the material experimented on, whereas we have to be content with the material, whatever it is, composing the stars. But, as you see from the table, the physicist is also interested in finding how the absorption changes for different wave-lengths. We can follow him in this, and even do better than he, because he is restricted by certain practical difficulties to a narrow range of wave-length, whereas we can explore a range of wave-length cov-

ering a ratio of at least 10 to 1 by using stars of different temperatures. It is true that our results are not yet very accurate; we have only one star, Capella, for which a really good determination is possible, but for other stars rough values can be found. The terrestrial results indicate an extremely rapid change of absorption for slight alterations of wave-length (as is seen from the table); the astronomical results, on the contrary, give a nearly steady absorption-coefficient. We can not yet detect certainly whether it increases or decreases with wave-length; at any rate, there is nothing like the rapid change shown in the foregoing table. This profound discrepancy between astronomical and laboratory results leads us to inquire more deeply into the theory of absorption in a star. It will be found that there is a good reason for it.

We have been taking advantage over our cloud-bound physicist by having a preliminary peep at an actual star. We are not going to allow *him* to do that. He must not use astronomical observations to determine the opacity, but must be able to predict the astronomical value either from pure theory or from terrestrial experiments. This study is of special interest because it plunges us at once among those problems which are most exercising practical physicists at the present time. We started to explore the interior of a star; we shall presently find ourselves in the interior of an atom.

It is now generally agreed that when ether-waves fall on an atom they are not absorbed continuously. The atom lies quiet, waiting its chance, and then suddenly swallows a whole mouthful at once. The waves are done up in bundles called quanta, and the atom has no option but to swallow the whole bundle or leave it alone. Generally the mouthful is too big for the atom's digestion, but the atom does not stop to consider that. It falls a victim to its own greed—in short, it bursts. One of its satellite electrons shoots away at high speed, carrying off the surplus energy which the atom was unable to hold. The bursting could not continue indefinitely unless there were some counter-process of repair. The ejected electrons travel about, meeting other atoms; after a time a burst atom meets a loose electron under suitable conditions, and induces it to stay and heal the breach. The atom is now repaired and ready for another mouthful as soon as it gets the chance.

From this cause a big difference arises between absorption of X-rays in the laboratory and in the stars. In the laboratory the atoms are fed very slowly; the X-ray bundles which they feed on can only be produced by us in small quantities. Long before the atom has the chance of a second bite it is repaired and ready for it. But in the stars the intensity of the X-rays is enormous; the atoms

are gorged and can not take advantage of their abundant chances. The consumption of food by the hungry hunter is limited by his skill in trapping it; the consumption by the prosperous profiteer is limited by the strength of his digestion. Laboratory experiments test the atom's skill in catching food; stellar experiments test how quickly it recovers from a meal and is ready for another. That is why the absorption follows a different law in the two cases.

To predict the stellar absorption-coefficient we must accordingly fix attention on the rate of repair of the burst atoms. The atom is wandering about advertising a vacancy for an electron, and numbers of ejected electrons are rushing about on holiday. Many electrons will come up, look at the situation, and go off again. How is the atom to trap the electron into taking up the situation? I will give you the solution of this problem, which I am inclined to think fairly probable, though I have not found many who agree with me. We may compare the electron to a stray planet entering the solar system from outside, bearing in mind, however, that the planets (satellite electrons) must be supposed to repel the invader, and the sun (positive nucleus) attracts it. Dynamics teaches us that provided no actual material collision occurs the intruder will scarcely ever be captured, but after stirring up things a little will retreat again towards infinity. There are exceptions, as when the sun and Jupiter conspire to capture a comet, but these would be very rare in the conditions corresponding to an atom.[2] Mere delicate persuasion being of no avail, there seems nothing left but for the atom to secure its electron by brute obstruction. For this reason I take the view that usually the capture of an electron occurs through its running against the positive nucleus of the atom. This nucleus has a highly complicated structure, the iron nucleus, for example, consisting of eighty-six distinct charges arranged in some kind of equilibrium. If by accident an electron runs full tilt into this packed mass, it will agitate it and lose energy in so doing. It will rebound no doubt, but with smaller velocity, insufficient to carry it out of the sphere of attraction of the atom.[3] By a process of exclu-

[2] In some cases the intruder would turn the tables by carrying off a regular planet, thus compensating for the occasions when it was itself captured. Probably, as regards repair of the atom, as much harm as good would be done on the average.

[3] The kinetic energy at the moment of collision with the nucleus is enormously greater than the kinetic energy before entering its sphere of attraction; so that a very small *proportionate* change of kinetic energy by collision would wipe out the original energy of the electron. The imperfect elasticity of the collision is a dynamical consequence of the complex structure of the nucleus. A collision of two simple charges may be perfectly elastic, except that that would apparently prevent a hydrogen nucleus from ever recovering its electron.

sion this seems the only method consistent with dynamical laws by which the atom can secure the electron needed for its repair. Therefore I have concluded that the actual electron trap is none other than the positive nucleus—a region at the center of the atom known to be about 10^{-12} cm. in radius. It must be remembered that the nucleus attracts the electrons, and will sweep into the trap many which were not initially aimed at it.

This theory has been adversely criticized, mainly on the ground that it is entirely accordant with the laws of dynamics. At first sight that might not seem a grave objection, but we have got so used to the atom behaving in a way which violates the classical laws that any theory which does *not* violate them is liable to be viewed with suspicion. Whilst admitting that there are uncertain possibilities in the mysterious region in the interior of an atom, we must note that the present problem belongs to a class of investigations in which the usual dynamical laws are applied by physicists, often with much success. It concerns the motion of a free electron—not yet forming part of any permanent quantised system—a problem which occurs in the theory of conduction of electricity in metals, in thermionic phenomena, and in the scattering of α and β particles. In these problems physicists are accustomed to assume (rightly or wrongly) that the classical laws of dynamics are observed, and we have only followed their (good or bad) example. In particular, in Rutherford's experiments on scattering, the classical laws of force are found to hold good almost to the boundary of the nucleus itself. There seems to be a fair presumptive evidence that our stellar problem should be attacked in the same way, although we admit that unknown circumstances may intervene.[4]

The strong point in our favor is that this theory actually does give the value of the absorption-coefficient agreeing with astronomical observation. Thus, for Capella the calculated value is 110, as compared with the observed value 150. There are certain doubtful factors which permit of the result being varied by a factor 2, or possibly 3, and we lay no stress on the precise accordance. But it appears to be possible to predict on this hypothesis the brightness of a star of known mass like Capella to within a magnitude—which amply solves the problem proposed to our physicist on the cloudy

[4] Whilst the fast-moving particles undoubtedly penetrate the atom in the way we have assumed, it is held by some that slow-moving electrons (as in the stars) are turned back at the surface. The idea seems to have originated at a time when the positive charge of the atom was thought to be a large sphere co-extensive with it; and it seems out of keeping with modern views. It is ignored in current theories of conduction of electricity. Even if it were conceivable that a neutral atom could so ward off an electron, the strongly positive atoms in the stars could scarcely exclude it.

planet. It may be added that the theory also explains why the absorption in giant stars is nearly independent of the wave-length; but that is a more elementary result, which becomes apparent as soon as we realize that the problem is concerned with the rate of repair of the atoms. Many alternative theories of the conditions of repair would lead to the same conclusion.

The store of ethereal heat and the store of material heat in the star may be compared to the accumulators of a power station. We have not yet discovered the dynamos. The accumulators would run down in a few thousand years if they were not replenished. What is the source of the energy maintaining (and during the ascent of temperature increasing) this internal store? We believe now that the source is sub-atomic energy. One theory is that inside the star the simpler elements are gradually being built up into more complex elements, and energy is liberated in the process; a more drastic view is that matter is being entirely annihilated, setting free the whole of its energy of constitution. Taking the first theory, the most conspicuous known case is in the formation of helium from hydrogen. We do not know how to make helium from hydrogen, but we know that it is so made; we know also that 0.8 per cent. of the mass disappears in the process, and this must be the mass of the energy—ether waves—liberated when the change occurs. Ether waves weigh very light, and the energy available from this source is colossal. If 5 per cent. of the star consists of hydrogen, which turns into helium as a first step in the formation of the higher elements, that would provide energy sufficient for all reasonable demands.

We might, perhaps, expect that the earliest stars would consist almost entirely of hydrogen, the evolution of the higher elements having little chance of beginning until the interior became hot enough to stimulate the process. But a difficulty arises here. For astronomical reasons it seems impossible to admit that even the earliest stars contain more than a very moderate proportion of hydrogen. I have referred to the fact that our calculations have been practically independent of the chemical constitution of the star; but one reservation ought to have been made—*provided it is not made of hydrogen*. Hydrogen gives results differing widely from all the other ninety-one elements. To assume hydrogen as the material would in most cases destroy the general accordance of theory and observation; indeed it is a way of realizing the goodness of this general accordance to note how it disappears when hydrogen is substituted instead of a normal element. I think therefore that the process of element-building from protons and electrons must have begun before the stellar stage is reached. This is a curious

detached piece of knowledge to have come across in exploring the interior of a star—to be able to deny that it is mainly composed of hydrogen, though any of the other ninety-one elements may be present to any extent; and it is still more curious that hydrogen should be the element with which we were tempted to build the stars, so that this apparently random denial hits the mark.

Admixture of hydrogen diminishes the proportion of ethereal energy and ethereal pressure, and so permits gravitation to aggregate larger masses The occasional formation of stars of exceptionally large mass (20 to 80 times the sun's) may be due to the accidental prevalence of hydrogen in the region where they originated —that is to say, the material was in a more primitive state as regards evolution of the elements.

I do not think we need be greatly concerned as to whether these rude attempts to explore the interior of a star have brought us to anything like the final truth. We have, I think, been able to recognize some of the leading factors participating in the problem, and to learn how many varied interests are involved. The partial results already attained correspond well enough with what is observed to encourage us to think we have begun at the right end in disentangling the difficulties, and we do not anywhere come against difficulties which appear likely to be insuperable. The fact is that gaseous matter at very high temperature is the simplest kind of substance for a mathematical physicist to treat. To understand all that is going on in the material of this desk is a really difficult problem, almost beyond the aspirations of present-day science; but it does not seem too sanguine to hope that in a not too distant future we shall be able to understand fully so simple a thing as a star.

FOSSIL MAMMALS AT THE COLORADO MUSEUM OF NATURAL HISTORY

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

IN the year 1904 Mr. O. A. Peterson of the Carnegie Museum at Pittsburgh was looking for fossil mammals in Nebraska. In the month of July he visited Captain James H. Cook at his stock farm at Agate Spring. Shortly after his arrival, Mr. Cook's son Harold took him out to see a locality where fragments of bones were scattered on the surface. These bones had been noticed by the elder Cook as early as 1877, but supposed to be of no great consequence. Mr. Peterson proceeded to investigate and soon discovered that there was a rich deposit of mammalian remains of Tertiary age, a deposit which has since become famous as the Agate Spring Quarries.

It was fortunate for science that the Cooks were resident at Agate Spring. In other localities, paleontology has suffered severely from vandals, or has been hindered by stupid attempts at commercial exploitation. Captain James Cook, his wife and sons united with the utmost zeal and good will to render every possible assistance to those who were competent to open up and investigate their bone quarry, which proved to be one of the finest known. The eldest son, Mr. Harold Cook, was seventeen years of age when Mr. Peterson arrived. Entering into the spirit of the discovery, he soon became an active student of vertebrate paleontology. In the years 1907 to 1909 he attended the University of Nebraska and Columbia University, where he qualified as an expert geologist. Gladly encouraged by the older workers, he rapidly came to the front, and is now recognized as one of the authorities on the vertebrate life of the American Tertiaries.

The first species of mammal to be collected at the Agate Spring locality was apparently the large Chalicotheriid *Moropus*, which was obtained by Professor E. H. Barbour, of the University of Nebraska, July, 1892, twelve years before Mr. Peterson's visit. It was not until 1908, however, that this animal was named. Professor Barbour, in a publication of the Nebraska Geological Survey, called it *Moropus cooki*.[1]

[1] Holland and Peterson (1913) regarded *Moropus cooki* as a synonym of *M. elatus* Marsh, but Osborn (1917) considers it a valid species. The term *M. elatus* belongs to a later period.

In 1911 the American Museum of Natural History, with the cooperation of the Cooks, entered the field and during a number of years excavated numerous remarkably fine skeletons.

In 1916 a visitor to the Colorado Museum of Natural History at Denver, spoke to the director, Mr. J. D. Figgins, about the work at Agate. He had visited the place and was very much impressed by the discoveries made, and by the courtesy of the Cooks. Would not Mr. Figgins get in touch with them, and perhaps secure some of the materials for the Colorado Museum? The director accordingly went to Nebraska, and arriving at the spot asked whether arrangements could be made for his museum to excavate in some corner of the field. The generosity of the response astonished him. The fossils are overlaid by heavy sandstone, ten to fifty feet thick, which has first to be removed. At a certain place this arduous work had already been done, and a very fine lot of bones was exposed. Mr. Figgins was invited to help himself, and with suitable assistance secured the admirable specimens now exhibited in Denver. Thus, said Mr. Figgins, in describing the incident, Harold Cook is fairly to be called the father of our work on Tertiary mammals.

In former times, it had been a matter for regret that, although fossil vertebrates were so frequently found in the Rocky Mountain region, nearly all the specimens went to museums in the eastern states, or even to Europe. Colorado had never been willing to spend its money in excavating such specimens, or in building museums where they could be exhibited. This was not altogether surprising, for the state was comparatively new and poor, and the very profits made from her mines mostly went elsewhere, to swell the wealth of already rich groups of men. Yet, with the increase of population and the development of higher education, the point of view necessarily changed, and while we have not progressed very far, we are at least on the way to finer things. The city of Denver has established an excellent museum in one of its parks, supported mainly by municipal funds, after the manner of the American Museum in New York. In the center of the city is the State Museum, particularly noteworthy for its work in botany, but as yet receiving quite inadequate support. The Colorado Museum or City Park Museum, as it is often called, has many very fine mounts of mammals and birds, shown as in their natural haunts; but at present we are concerned with the fossils. Having got a fair start at the Agate Spring quarry, with the result of arousing a certain amount of interest in Colorado, it was natural that when Mr. H. D. Boyes, of Wray, Colorado, found some fossil bones, he should communicate with Mr. Figgins. Here, again, was the fortunate coincidence of a liberal and scientifically minded discoverer with a really first-class find. Wray is near the border of Yuma County,

FIG. 1 Excavating *Trigonias osborni*, a fossil rhinoceros, Weld County, Colorado (Oligocene).

only a short distance from the Nebraska line. Mr. S. N. Hicks has furnished an annual subsidy which has made it possible to keep a group of men in the field each summer. The find at Wray proved to be of much later date than that at Agate Spring. The numerous specimens, including two new species of the elephant group, a new sabre-toothed tiger, etc., have been studied by Mr. Harold Cook, who assigns them to the Pliocene. Thus, they are of special importance, as our knowledge of that period in our region has been very defective. Previous to the deposition of the stratum containing bones, the surface of the country has been eroded so as to remove all of the Eocene, Oligocene or Miocene deposits, exposing the Pierre (cretaceous) marine shales. Right on the surface of this is the thin Pliocene deposit, full of skeletal remains.

The Pawnee Buttes, high elevations standing isolated in the plains of Weld County, Colorado, represent the remains of a great Tertiary deposit. They have long been known to yield vertebrate fossils, but it has been supposed of late that nearly everything of value had been removed. This is evidently not the case, as Mr. Figgins had the good fortune to discover a ranchman in that vicinity, who, digging post-holes, had thrown out a fragment of bone. This

FIG. 2. Scene of excavations; Weld County, Colorado (Oligocene).

FIG. 3. Repairing large specimen in the museum.

FIG. 4. Slab of rock containing remains of the rhinoceros *Trigonias osborni*, from Weld County, Colorado, exhibited in the museum.

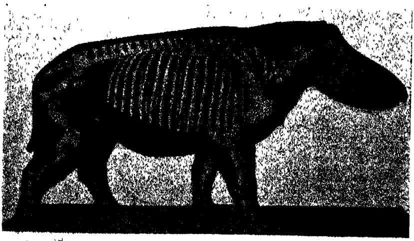


FIG. 5. Skeleton of *Trigonias osborni*, with restoration on other side.

FIG. 6. Model of *Teleoceras fossiger,* another extinct rhinoceros, from Yuma County, Colorado.

suggested an excavation, and the result was that the Colorado Museum party unearthed splendid material of *Titanotherium.* Not far away the bones of *Trigonias,* a species of rhinoceros, were obtained; and further investigations resulted in finding a whole series of mammals of Oligocene age. It has not yet been possible to fully report on these, but it is at least known that this supposedly exhausted and well-known locality will yet add much to our knowledge of ancient life.

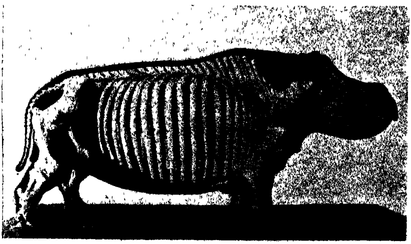


FIG. 7. Skeleton of *Teleoceras fossiger;* the other side is shown in Fig. 6.

Thus, by taking advantage of opportunities, with the aid of a few who could appreciate the potential educational and scientific gains, it has been possible to inaugurate a movement for the preservation and investigation of the remains of extinct vertebrates in Colorado, with facilities which are at least reasonably adequate. No one can doubt that the work will develop rapidly, as it has already done, and will at length assume very extensive proportions. Support will, we trust, increase with the opportunities arising from new discoveries, so that it may no longer be said that we must send our large fossils elsewhere from sheer inability to take care of them.

When the fossils have been found, dug out and brought to the museum, there is still a great deal to do in preparing them for exhibition. In the Colorado Museum the exhibits are so planned as to show how the fossils occur in the rocks and also the appearance of the animals in life. When I visited the museum last December, I was astonished to see what appeared to be a stuffed rhinoceros of a species quite unfamiliar to me. Going to inspect it more closely, I soon perceived that it was a model of half the animal (*Teleoceras*), the skeleton being exposed on the other side. It is exceedingly lifelike, and a more instructive exhibit could hardly be devised. In the preparation room I found large oil paintings, showing the country as it may have appeared in Tertiary times, with the various animals roaming about. These will be used as backgrounds for the exhibits of skeletons which are now being prepared and studied, some of them evidently representing animals new to science.

THE LATE PRESIDENT HARDING RECEIVING MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES IN APRIL, 1921

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

A SELF-GOVERNING TURBINE

The wealth of Sweden lies largely in its water power. This amounts to about one and a fifth horsepower *per capita*, according to the calculations of Dr. Arrhenius, head of the Nobel Institute. Even the United States is not so rich in hydraulic resources in proportion to its population and is not yet making as much use of what it has.

The Swedes have broken to harness one quarter of their wild waterfalls and are preparing harness for those that are still running at large. They are not afraid of a coal famine, for they have always had one. From their wood and waterfalls they can get both heat and power, and they are making every effort to be as independent as possible of those countries which have inherited their wealth from the Carboniferous Epoch.

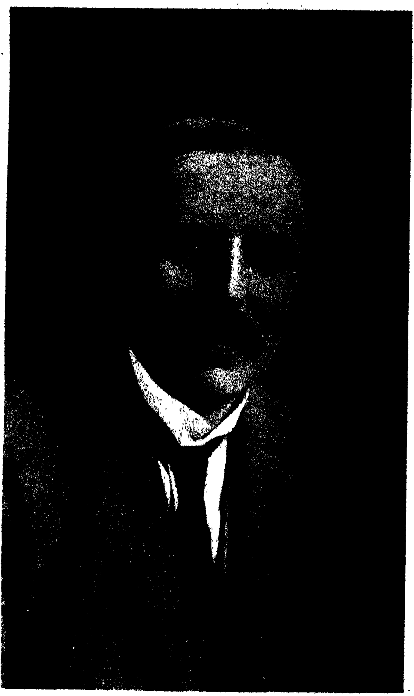
I never realized how many Swedes had wheels in their heads till I entered the Machinery Hall of the Gothenburg Jubilee Exhibition where their new inventions are displayed. There were turbines on every side and overhead. Turbines for water; turbines for steam; turbines for milk. Turbines three times as tall as I was and turbines that I could hold in my hand. It seemed that the spirit of De Laval had inspired the nation.

Among these various turbines were some of novel and curious form. One I took for a ship's propeller, instead of a water wheel, for it had only three blades and no rim. On inquiry I found it was called the Kaplan turbine and was just being developed in Sweden.

In order to secure the greatest efficiency as a power producer a turbine has to be constructed so as to run at a certain speed under a given head of water. But when the load, speed, flow or pressure changes, the turbine does not work so well as one of a different design would. To overcome this difficulty Professor Kaplan, of Brunn, has invented a waterwheel with adjustable blades and guide vanes which are automatically shifted to a different angle by a sensitive governor so as to secure the greatest possible efficiency whenever the conditions change. In this turbine the blades are reduced to four or three or two and are made short and broad, being so set as to pass the water through in a continuous positive eddy without reverse currents anywhere.

A turbine of the Kaplan type is now being constructed by the Kristinehamn works for the Royal Swedish Waterfall Board to be installed at Lilla Edet. In this a single wheel of 19 feet diameter, weighing 62 tons, will give 10,000 horsepower under a head of 22 feet, and can take an overload of twelve per cent. Its specific speed is 640.

The specific speed is the number of revolutions per minute that a similar turbine would make if of such a size as to give one horse-power under a unit head of water, which in the European system is one meter. The higher the speed, the less the efficiency, as a rule, but it is claimed for the Kaplan turbine that it will show an efficiency of more than eighty



Sir Ernest Rutherford
Cavendish professor of experimental physics at the University of Cambridge; President of the British Association for the Advancement of Science, meeting this month at Liverpool.

per cent. with a specific speed of over 800, a considerable gain over the speeds of 300 or 400 formerly customary. A recent installation of a Kaplan turbine shows an efficiency ranging from 84 to 86 per cent. with the horse-power varying from 57 to 99, and a specific speed of 718, the highest yet attained in Scandinavia. The conical construction of the outlet pipe, whether straight or bent, produces a suction below the wheel that adds to its power.

But its self-governing ability was what interested me most. If I slowed up the wheel of the model by the touch of my hand it adapted itself to the new condition as quickly as a gyroscope top when it is tipped. It was indeed a model—to human beings who often wobble and creak badly when their equilibrium is disturbed and waste much time and energy before adjusting themselves to changed conditions of load or motive power.

SCIENCE AS A RECREATION

Most people think of science as a serious and solemn thing, a strain upon the strongest intellect. So it is for the pioneers of scientific progress, but not for those who merely follow along behind.

The layman does not exaggerate, in fact, he does not begin to appreciate, the difficulty of original research, the devotion and self-sacrifice of men of science. A man may pursue a subject for years and then find that he has lost his labor through taking the wrong turn in the labyrinth of nature. He may count himself one of the fortunate if what he accomplishes in a lifetime is considered worthy of filling a footnote in some general compendium of science.

But however painful and slow a process may be the promotion of science, its results are intended to eliminate labor and economize time. The scientist toils that others may have an easier time. It is owing to the labors of a long line of electricians from Faraday to Bell that the housewife is able to telephone the grocer to send over the ice cream for dessert. If mechanics from Hero, of Alexandria, to Otto, of Germany, had not worked over engines we should not be able to take a hundred-mile ride in an auto any fine day.

Science is a thought-saving device and when applied to life it results in time-saving and labor-saving inventions.

Science means simplification. It substitutes a single rule for a million miscellaneous observations. To borrow a phrase from Poincaré, science consists in giving the same name to different things. The scientist links things together by whatever they have in common. If you have a lot of loose papers to carry, or sticks of kindling wood, you will do it easier if they are tied together in a single bundle. That is what the scientist is always doing, tying up fugitive facts into compact and portable packages. Learning the 36 combinations of the multiplication table is hard work, but once you have mastered them you become master of all the multiplications in the world. Newton's law, "Action and reaction are equal and opposite," covers in seven words all possible cases of the application of force.

Because some people have to study the sciences seriously, it is no reason why the rest of us should not chat about them or joke about them. We may make light of ponderous matters and even treat gravity with levity without danger of irreverence.

A NEW PATH TO OBLIVION

It is within the memory of many still living that science revealed to mankind means of escape from the pains of disease and surgery. Nitrous oxide and ether were used for amusement long before they were used for relief. Medical students in New England used to take laughing-gas or indulged in "ether frolics" for the fun of the thing without thinking of the possibilities of applying it in their profession.

But in 1844 a Connecticut chemist named Colton had a big back tooth pulled out after inhaling nitrous oxide and two years later, Dr. Morton, a Boston dentist, put himself to sleep with ether and then tried it on a patient who came into his office as he awoke. The use of anesthetics was bitterly opposed at first on the ground that pain was a punishment or a natural process and that it was cowardly or wicked to evade it, but the new practice prevailed and brought surcease of suffering to uncountable millions of men, women and children in the last seventy-five years.

Nitrous oxide and ether have been the chief means of producing complete unconsciousness, but now a new agent of anesthesia has entered the field that promises to rival or supplant both. This is ethylene, a gas composed of hydrogen carbon, long in use for illuminating, but which has recently been found by Professor A. B. Luckhardt, of the University of Chicago, to have the power of putting a person to sleep without the danger and unpleasant after-effects that sometimes attend the use of the older anesthetics. On inhaling the gas the patient passes quickly into insensibility and then into complete unconsciousness. The respiration and blood pressure remain regular and the muscles are relaxed. The recovery is remarkably rapid. Within three or five minutes the patient comes to his senses, usually without nausea. In the case of a severe operation on the leg the patient had to be kept under the influence for three hours and ten minutes continuously. Yet five minutes afterwards he had become conscious, got off the operating table himself and two hours later ate a meal.

In the four months that the new anesthetic has been in use at the Presbyterian Hospital in Chicago some 350 operations of all sorts have been successfully performed under its influence. A Chicago dentist has extracted teeth from about a hundred patients using ethylene in place of nitrous oxide. It has also been found useful in normal childbirth.

The discovery of the soporific effect of ethylene came through a curious chain of circumstances. In 1908 the carnation growers complained that they were losing money because the flowers they shipped to Chicago went to sleep when put in the greenhouses and the buds failed to open. A couple of botanists from the University of Chicago were assigned to the job of running down the reason of this floral "sleeping sickness" and found that it was due to the leakage of illuminating gas which contained four per cent. of ethylene. This is commonly added to city gas to increase its candle power. Plants are extremely susceptible to ethylene. Sweet peas will droop their leaves if the room contains one part of ethylene in a million of the air; a much more delicate test for its presence than any chemical reaction. This may be a reason why plants do not thrive and people get sleepy in houses where the gas fixtures are leaky.

Since the investigation now led out of the vegetable kingdom and into the animal it passed over into the hands of the physiologists who carried the experiments on up the scale of life, using frogs, mice, rats, guinea-pigs, rabbits, kittens and dogs successively as subjects. It was found that

ethylene brought the animals into unconsciousness in half or a quarter of the time necessary for nitrous oxide and that they recovered more quickly.

Finally Dr. Luckhardt and his colleague, Mr. Carter, having thus assured themselves of its safety and learned how to administer it, tried it on themselves and for several successive Sunday afternoons put themselves to sleep by the inhalation of ethylene. They have both been anesthetized a dozen times since without noticing any untoward symptoms.

The gas is inhaled with oxygen as is the custom with nitrous oxide. Between 80 and 90 per cent. of ethylene is sufficient in most cases to bring the patient to the point where a surgical operation may be carried on. Care must be taken of course to see that the gas is pure and also to keep it away from flames since ethylene, like ether vapor, is inflammable.

The brief history of ethylene as an anesthetic is a striking illustration of the acceleration of scientific progress in this century. In 1798 Humphry Davy, then only 22, discovered nitrous oxide and suggested that it might be used to stop the pain of surgery, but it was half a century before this hint was acted upon, fifty years of unnecessary pain and loss of life. But in the case of ethylene the progress from pinks and peas to professors and patients was made with swift sure steps and in the course of a few months humanity was receiving relief from this new source.

When it was proposed to erect in Boston a monument to the discoverer of anesthesia, a hot discussion took place as to who was entitled to the honor. Should it be Dr. Morton, who pulled the first tooth with ether, or Dr. Jackson, who told him how to use it. Dr. Oliver Wendell Holmes then suggested that the statues of both claimants be put on one pedestal inscribed "To Ether." This is one of the jokes that no Englishman can understand, for he would pronounce it "eye-ther."

If ethylene proves to be as useful as it seems to be, room must be found on the same pedestal for Dr. Luckhardt, even though it spoil the pun.

CATCHING UP WITH CHINA

We Americans may be a little slow in catching on to old ideas, but once we do get them we push them for all they are worth.

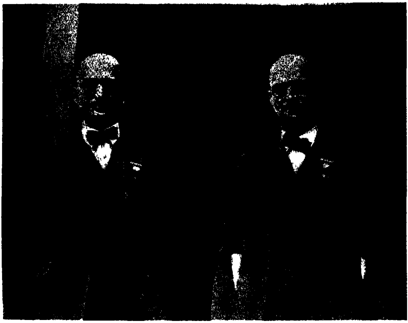
Take the soy bean, for instance. That was first introduced to America in 1804, but it was a hundred years before we could be induced to take it seriously. We started in therefore five thousand years behind China and Japan in the cultivation and use of the soy bean, for there it ranks next to rice. But in the last ten years it has rapidly come to the front as one of our major crops and it is likely in the next ten years to go ahead of oats in acreage in some of our states. Wherever corn or cotton flourishes the soy bean can be grown, and few crops have so many strings to their bow. The latest bulletin of the Department of Agriculture lists fifty different uses for soy products, and doubtless Yankee ingenuity can and will add more when we get our minds to working on it.

Even the Japanese have not exhausted their ingenuity in this field, long as they have been at it. A Japanese scientist named Sato has invented a new plastic which he has called, according to American precedent, "Satolite." It is made by precipitating the protein with sulphite, hardening it with formaldehyde, and molding it under heat and pressure into combs, buttons and whatever we make from hard rubber or celluloid or the casein of milk.

The soy bean is rich in protein and fat, and lacking in starch, in that more like animal than like vegetable food. You can make a milk out of it by simply soaking the dried beans till soft, then crushing fine in a meat grinder, boiling in three times the volume of water for half an hour and straining through a cloth. If you do not like the flavor you can add vanillin or something else. This vegetable milk sometimes agrees with children when cow's milk does not. It can also be used for cakes and custards.

The soy milk may be made into curds and cheeses of various sorts which form a large part of the diet of orientals, but for which we have not yet acquired a taste. Soy meal has come into common use in America, not only as a cattle food, but also for bread and pastry mixed with three parts wheat flour.

Soy sauce has long been familiar but quite unknown to us. We did not recognize it under its aristocratic English name and its added flavors. But when the high cost of living drove us to the chop sueys, we became acquainted with the cruet of brown salty sauce called "shoyu," and we found, as the Chinese had found thousands of years before, that a sprinkling of it would make tasty a large lot of rice and serve as substitute for meat, both in taste and nutriment. Soy sauce is of several sorts. If you want it strong take the Korean If you want it sweet take the Japanese.



—*Wide World Photos*

DRS. W. C. AND W. H. TUCKERMAN

Twin brothers who practice medicine in partnership at Cleveland, Ohio. Though known to practically every delegate attending the convention of the Ohio State Medical Association, Drs. W. C. and W. H. Tuckerman, twins of Cleveland, Ohio, caused confusion among the visitors by their almost identical dress and personal appearance. Both doctors practice together.

It is made by fermentation and the flavor depends upon the way it is brewed and the length of time it is left to ripen. To suit the palate of a Korean connoisseur the jars must be exposed to the sunshine by day and covered by night for a period of thirty years. We Americans, when we get to making it, will undoubtedly speed up the process

So far the oil is the most in demand of the soy products. The beans contain from 18 to 20 per cent. of a fine palatable oil, which we have imported at the rate of a hundred thousand tons in a year, but which we are now growing for ourselves. It can take the place in part of cotton-seed oil in vegetable substitutes for lard and butter, and of linseed oil in paints. Formerly the oil went mostly to Germany and England, but the war made a shift in the currents of Pacific trade, and we learned to appreciate its value But we have a lot to learn yet before we catch up with the orientals in the utilization of this multifarious bean.

PHOSPHATES AS STIMULANTS

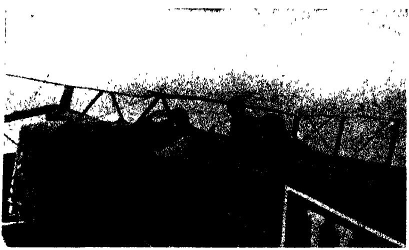
During the war we heard all sorts of wild rumors about the German soldiers being given some secret chemical that endowed them with supernormal energy as they charged the trenches or endured forced marches. Doubtless various things were tried, including that old and unreliable stimulant, alcohol, and the newer and less exciting energizer, sugar

But it has now been disclosed that most remarkable results in the increase of muscular power and endurance were obtained from the use of a well known salt, called by the chemist "sodium dihydrogen phosphate" This was given to the shock troops as they entered battle or during long marches in the form of a drink. To avoid the influence of psychological suggestion, which has invalidated so many tests with "poison squads" and experimental subjects, other battalions were served with a sham drink sweetened and flavored the same, but acidulated with tartaric instead of phosphoric acid. At the end of a hard hot day the troops that had been treated with the phosphate were fresher in spirit and less fatigued in body than the others for some reason mysterious to them.

Since the war it has been found that giving phosphate drink to coal miners and farm laborers increased their monthly output without extra exertion. Horses and oxen given an ounce of the salt a day did more work and gained flesh. Here there could be no deception due to the imagination.

This practical and promising method of increasing human and animal efficiency came from the investigations of one of the foremost of German physiologists, Professor Gustaf Embden, of Frankfort University, on the chemistry of nutrition. According to this theory muscular energy comes from the breaking down of a substance called "lactacidogen," which he regards as a compound of sugar and phosphoric acid. This breaks down, when the muscle contracts, into lactic acid and phosphoric acid. Lactic acid, as it has long been known, accumulates in a fatigued muscle and has to be recombined or oxidized before the muscle can work again. So Embden reasoned that adding phosphate to the diet would hasten the combination of the phosphoric acid with more sugar and so relieve the fatigue. The war gave him the chance to experiment on whole regiments at a time and the results seem to confirm his theory.

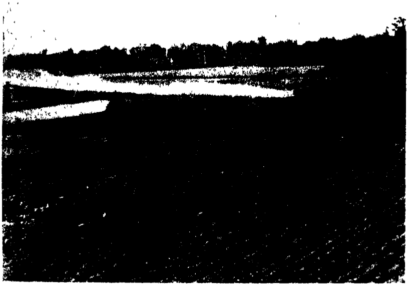
The new stimulant has the advantage over alcohol or the alkaloids in that it is a natural factor in bodily process, and also in that there is no danger of intoxication from an overdose or of forming a habit. Doses up to a quarter of an ounce a day were given to the soldiers and laborers.



—*Wide World Photos*

EXPLORING BY AEROPLANE

The 1923 Franco American Expedition exploring the ruins of Carthage under the leadership of Count Byron Kuhn de Prorok, Prince Edgard de Waldeck, who was killed in a motor accident at Juan les Pins on his return from Carthage, acting as observer in the airplane piloted by Lieutenant Peletier d'Oisy. In this flight they traced an under water sea wall and saw columns still standing 100 yards off the shore. They also searched for a wrecked galley of Punic time in the Gulf of Tunis.



—*Wide World Photos*

SPRAYING COTTON FROM AEROPLANES

Experiments are being made by the army at Tallulah, La. The dusting plane flies at an elevation of about 25 feet.

More than this, and sometimes much less than this, has a laxative effect.

The report of these experiments is likely to multiply calls for phosphate drinks at the soda fountains, but the anticipated increase of muscular vigor may fail to be felt, for when the man behind the marble counter mixes a phosphate he throws in a dash of a very dilute solution of phosphoric acid, and a person would have to take some fifty such drinks to get the amount used by the soldiers

INTARVIN

Science Service

The invention of a new form of artificial fat that can be digested by diabetic patients was announced by Dr. Max Kahn at a meeting on August 2 of the medical staff of the Beth Israel Hospital, New York City.

At that hospital feeding with the new fat has given relief in thirty cases of acidosis due to diabetes. One man was carried into the hospital for the purpose of having his leg amputated since it was attacked with gangrene But after the artificial fat had been added to his diet the acidosis was stopped, the sores healed up and four weeks later the man walked out of the hospital on his own two legs.

Dr. Kahn, who has charge of biological chemistry in the College of Physicians and Surgeons of Columbia University and of diseases of metabolism at the Beth Israel Hospital, has been working for a year and a half to make a fat that would not break down into acid products as do natural fats in cases of diabetes From recent researches in the chemistry of nutrition he came to the conclusion that a fat with an odd number of carbon atoms would serve the purpose. But such a fat could not be found in nature so it had to be made to order.

The investigations to simplify the method of manufacture and the carrying through of the design of the plant apparatus and installation of equipment have been conducted by Professor Ralph H. McKee, professor of chemical engineering, Columbia University, and required the services of two assistants for six months It was through this investigation that the process has been simplified so that instead of material costing $300 or even $100 a pound, it can now be made in a factory and sold for $8 a pound, and probably this cost will decrease still more once production is well under way. A pound will last a patient from a week to three weeks.

A manufacturing plant has been built in Long Island City and 200 pounds of the new product is turned out in a week. It has been named "intarvin," meaning "intermediate fat" because the molecule contains 17 carbon atoms and is therefore intermediate in composition between the ordinary fats carrying 16 and 18 carbon atoms

Intarvin is a white crumby substance, tasting something like tallow but is not so soft. It is either eaten straight or mixed with a little tasteless mineral oil or made up into a mayonnaise or shaken up with buttermilk or baked in gluten bread. The diabetic patients find the new fat quite eatable and it satisfies the craving for fat common in the disease.

It is a curious coincidence that within the year 1922 two remedies, Insulin and Intarvin, have been invented for diabetes, which, though one of the most common and serious of diseases, has hitherto baffled medical skill. Insulin, which was discovered by Dr. F. G. Banting, of the University of Toronto, is an extract of animal pancreas which when injected into the veins restores temporarily the power to assimilate sugar. Intarvin is a synthetic fat which is assimilable by diabetics in whom natural fats produce an excess of acid. Neither insulin nor intarvin is regarded at

present as a permanent cure for diabetes, but both restore temporarily the digestive powers, the former for sugars, the latter for fats, but each increases somewhat the ability to handle the other types of food.

After preliminary experiments on animals the new treatment was tried first on a diabetic woman of 47 who had been in the hospital a year awaiting an operation for tumor, but she was so run down that it was not thought safe to operate. She was put on a fat-free diet to free her system from the injurious acids, but these still continued to be formed from the body fats. When a few ounces of intarvin was added to the diet the excess of acids and sugar disappeared within forty-eight hours. She has since been kept free from acidosis for 14 months by use of the intarvin fat.

Acidosis may be caused by starvation as well as by diabetes, so the next experiment was tried on a normal man. A young Swedish prize-fighter was induced by a pecuniary consideration to go without food for 74 hours. It was then found that he was excreting the acid products of unassimilated fat. But when he was given four ounces of the artificial fat mixed with the same amount of seven-times boiled string beans his digestion next day was normal. But when he took butter with the beans he was not able to digest it. Of the artificial fat 95 per cent was digested.

Here is a case of the use of "high brow" science. The discovery of this new treatment for diabetes comes from the study of the structure of the fat molecule and how it breaks down in the body. The molecule of a fat consists essentially of a long chain of carbon atoms connected together. The number of carbons varies with the fat, but is always an even number in natural fats. In stearic acid, for instance, which is the principal constituent of beef tallow, there are 18 carbon atoms in the chain. All of the carbons carry hydrogen atoms attached, except the carbon atom at one end of the chain which carries oxygen.

When a fat is burned up in the body to provide heat and energy, it is the oxygen end of the chain that is first attacked. Two carbons at a time are broken off until the whole molecule is reduced to carbon dioxide and water. Starches and sugars are normally burned, that is, oxidized, to the same harmless products.

A diabetic patient can not digest sugars and starches and so is forced to draw upon fats for his nutriment. But he can not completely break down the fat molecule. Instead of reducing it to its lowest forms, carbon dioxide and water, he can only cut down the chains to four carbons, which leaves in the body a pernicious compound known as aceto-acetic acid. This condition is known as acidosis. The presence of such acids prevents the blood from carrying off the waste carbon dioxide to the lungs for elimination, and the patient finally sinks into a state of coma, followed by death.

Since the carbon chain breaks down two at a time, it would follow that a fat molecule containing an odd number of carbons could not break down so as to leave the chain of four carbons that form the harmful acids.

This is the theory on which Dr. Kahn and Dr. McKee have worked. Starting with beef tallow they get out the stearic acid which contains 18 carbon atoms in its molecule. Then by oxidation they cut off one carbon atom from the chain leaving 17, a compound known to chemists as margaric acid. This is then recombined with glycerine forming a neutral fat, which, as the hospital tests have shown, can be digested by diabetics.

Neither margaric acid nor any fatty acid with a long chain of an odd number of carbon atoms occurs in any natural fat or oil. Some such compounds have been made in the laboratory but only a gram or so has been produced as a chemical curiosity. This is the first time that a purely artificial food has been manufactured in hundred pound lots for use as a regular article of diet.

THE SCIENTIFIC MONTHLY

OCTOBER, 1923

ANCIENT INSECTS; FOSSILS IN AMBER AND OTHER DEPOSITS

By Professor CHARLES T. BRUES

BUSSEY INSTITUTION, HARVARD UNIVERSITY

FRAIL creatures of the air and wholly destitute of a true bony skeleton, insects do not lend themselves so readily to fossilization as do many other organisms. The calcareous shells of molluscs and of several other types of invertebrate life, the siliceous skeletal elements of some other animals and plants and the bony internal skeleton of vertebrates are eminently suited for preservation, and it is only to be expected that these should be abundantly represented in sedimentary deposits, even of great age.

Nevertheless, Nature has conspired in several ways to make the task of the insect paleontologist easier and more profitable than the overworked entomologist might have dared to hope, had he remained wholly immersed in his job of sorting out the 10,000,000 living species of insects.

You may wonder why he has ever left such a permanently assured job even long enough to inquire into the possibilities of another, no matter how lucrative it might promise to be. You will understand, however, that it has been only when he wished to devote a few spare moments, stolen from his sabbatical leave, to some recreational, though kindred subject that these family skeletons have been exposed. Consequently, the vast opportunities for paleontological investigation have been seriously neglected by all but a few very inquisitive workers.

The fortunate circumstances that have aided the insect paleontologist are: First, the fact that the skeleton of the insect—if we may thus designate the wholly organic hard parts of the body—are entirely external and may thus be examined in the most minute detail in superficial view; and second, that the earlier insects, which have suffered more severely from the ravages of time, were larger

than most living species, some of really gigantic size; finally, many Tertiary insects are so wonderfully preserved that even the microscopic body-hairs and color can be made out on the surface of the finely laminated shale within which they are imbedded, while the specimens found in amber are still more nearly perfect.

Before discussing the Tertiary amber-fauna, it seems advisable to refer very briefly to its precursors, so far as they have been examined. No authentic insect remains are known from the Silurian or Devonian periods, although insect-like creatures probably existed at that time, but in the earlier deposits of the upper Carboniferous true winged insects appear. These early forms were of very generalized structure and have been designated as the order Paleodictyoptera. They were undoubtedly close to the ancestors of modern insects, as they possessed in combination the characteristics of several of the more primitive living orders. They must have been quite abundant, and over 100 species, representing more than 20 families, have so far been discovered; but the group did not persist beyond the upper Carboniferous.

By the middle portion of the upper Carboniferous the active evolution of the Paleodictyoptera had given rise to several more specialized groups, and these clearly forecast the differentiation of insects into some of the modern orders. Thus, the living Orthoptera were represented by the Protorthoptera, embodying certain characters of the common grasshopper or locust. The Protoblattoidea represented the proud ancestors of the despised domesticated cockroach. The Protodonata, some with a wing expanse of two feet, were glorified dragonflies, soaring through the luxuriant forests of the French coal-measures. Similarly, the modern may-flies were represented by generalized precursors. The higher living orders may also be traced through a common stem to the extinct order Megasecoptera. Finally, before the close of the Carboniferous, the first modern insects, true cockroaches, appeared.

Fossils of Carboniferous age are known from numerous localities in both Europe and North America, most abundantly in Commentry, in France, and at Mazon Creek, Illinois (Fig. 1).

The Permian introduces several additional modern orders, including true may-flies, stone-flies and mantids. Here appears also another group, the Protohemiptera, known from a single specimen, apparently intermediate between the Paleodictyoptera and the present-day order Hemiptera, one of the most highly specialized groups of insects, that appears in the upper Permian, at the same period that certain very primitive scorpion-flies are known to have existed.

The cockroaches dominated the Permian; numerous genera and

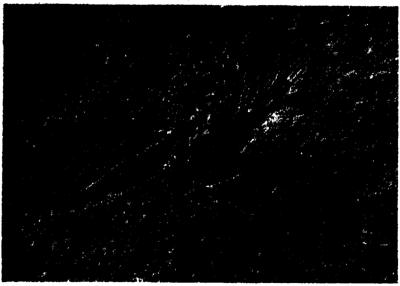


FIG 1. Wings of a primitive Carboniferous cockroach, *Blattinopsiella pygmaea* Meunier, from Commentry. After Meunier.

species, some of them very closely allied, have been found, although only a comparatively small number of Permian insects have come to light. These are from scattered localities, particularly in Germany and the United States. At Cassville, West Virginia, are the remains of an abundant fauna from whence already 40 species of a single genus of cockroaches (Phyloblatta) have been described. Of this same Phyloblatta nearly 90 Carboniferous species have been recovered from various places in both hemispheres. Such a condition is very similar to that exhibited by some modern genera of insects which include many closely related species. As the fossil species must be classified almost entirely on the basis of wing-venation, it is of course possible and quite probable, indeed, that several related genera are here concerned, indistinguishable in the absence of the other body-parts.

Altogether, about 1,000 species of Paleozoic insects have been described.

Insects undoubtedly prospered throughout the Mesozoic era, although we have so far been able to learn comparatively little about them during the Triassic and Liassic.

The few Triassic insects known are referable to two orders, Coleoptera and Megaloptera, in addition to several orders previously mentioned. The Coleoptera, so abundant in the modern fauna, appear here for the first time, represented by beetles of quite ordinary appearance, which may in all probability be referable, at least in part, to living families.

The insect fauna of the Liassic period is somewhat better known and includes some true Orthoptera (locustids and crickets), Odonata (dragon-flies), Hemiptera, Homoptera, Neuroptera and Panorpatae (scorpion flies). Among these orders, several living families are represented.

The scorpion-flies are particularly interesting because they form the undoubted ancestral stem from which several of the highly specialized modern insects have been derived. Of the latter two appear before the end of the Liassic. They are the Phryganoidea (caddis-flies) and the Diptera (two-winged flies).

During the Jurassic period insects reached a very high state of specialization, and we have fortunately a tolerably good, although very incomplete picture of this fauna. The Lepidoptera (moths and butterflies) and the Hymenoptera (saw-flies, ants, wasps and bees) appear as two further offshoots from the aforementioned scorpion-flies. The Jurassic Hymenoptera include only the most primitive forms of the order, as the ants, wasps and bees did not appear till later. The Diptera, however, first seen as we have said in the Liassic, have progressed clearly towards their present stage of development. Jurassic insects are known mainly from the Bavarian lithographic limestone and from several localities in England. Further discoveries are undoubtedly destined to throw much light on the evolution of some of the recent orders and families.

The Cretaceous period is almost a blank from the entomologist's standpoint, although the existence of fossilized egg-masses, such as those of moths attached to leaves, and the presence of insect-galls on the leaves of plants show that the insects of that day had strikingly modern habits, especially in relation to the flowering plants which had reached a high stage of development.

In all, some 1,200 species of Mesozoic insects are known.

So far as our present knowledge goes, insects appear to burst forth in their full glory in the Tertiary as the culmination of a long evolution, the tedious nature of which I feel sure I have impressed upon you quite fully. Working onward from the Carboniferous they have thus paralleled in time quite closely the progress of the higher vertebrates and the Age of Mammals has become coincident with the Age of Insects. As a matter of fact these two groups of animals were already biologically linked in the Tertiary, as is evidenced by the occurrence of fossil fleas, bot-flies, mosquitoes and other blood-sucking flies.

About 7,000 species of Tertiary insects have been described, and there are very many others in collections awaiting study.

The Eocene we know must have supported an insect fauna very much like that of the present day. Although scarcely 300 Eocene

species have been described, they are sufficient to show that some modern genera are represented and that many of the fossil genera are quite similar to living ones. Nearly all the known species are from deposits in our own Rocky Mountain region which have not yet received extensive study.

Of all fossil insects, those of Oligocene age, imbedded in Baltic amber, are the most beautifully preserved, and by far the most satisfactory to study. Moreover, the supply of amber insects is almost unlimited. The finest collection extant, that of the Zoological Museum of the University of Königsberg, contains more than 100,000 specimens, and there are many smaller collections in various other places. As is well known, amber is the fossilized resin of certain coniferous trees, the Baltic amber derived, at least in great part, from *Pinus succinalis*, a fossil species related to our modern pines. After exuding from the tree, and while still in a viscous condition, many insects were caught on its surface, just as they are at the present day on the sticky mess of rosin and castor-oil, known as tangle foot, prepared for this specific purpose. Thus encased in the gradually hardened amber, the included insects are as perfectly preserved as though freshly mounted in Canada balsam, notwithstanding the lapse of several million years, or possibly of even 30 or 40 million years, according to some recent estimates. Some specimens are of course not so good as others. There were no professors of zoology handy to see that all specimens were properly dehydrated before mounting, that their appendages were neatly disposed in the balsam, and that air bubbles were carefully expelled by the gentle heat of an alcohol lamp before drying in a constant-temperature oven. Nevertheless, Nature has shown us what lasting preparations can be obtained without the use of a modern laboratory cluttered up with elaborate apparatus.

The most extensive amber deposits so far discovered occur along the Baltic coast of eastern Prussia, where their existence has been known for many centuries. At some places the deposits are worked for commercial purposes where they occur near the coast, and considerable quantities are also found cast up along the shore after storms. The individual masses vary greatly in size, but are usually small, ones weighing as much as ten pounds occasionally coming to light. The amber is always of decidedly yellow color, but varies greatly in shade, and also, which is more important from the paleontological standpoint, in transparency, for much of it is translucent or semi-opaque. The most probable assumption is that the present location of the Baltic amber beds is well removed from the original amber forests which occupied the more mountainous land to the north on the Scandinavian peninsula and in Finland, from

whence the relatively light amber was carried by streams and deposited along the lower Baltic levels.

Due to the manner in which the insects were caught by the exuding resin, there was a selection of particular kinds of insects. Naturally, no very large or powerful species were readily captured, and we find a conspicuous lack of those types which could readily free themselves from the resin. Also, since the resin accumulated upon the trunks of the trees, insects that regularly live a subterranean existence and those that normally remain upon the surface of the ground had little opportunity to come into contact with the fresh resin, and they do not generally occur in the amber. The forests were undoubtedly heavily shaded (Fig. 2), as are the coniferous forests of the present day, and sun-loving, flower-frequenting forms were consequently of infrequent occurrence. Thus we find that the bees, a group so abundant at the present time, are very poorly represented, known by only some fourteen recognizable species and forty specimens in all. The bees have been carefully examined by Cockerell, so that there can be no doubt of the scarcity of this group in amber. The same is true of the wasps, although to a lesser extent. These have not been extensively studied, and it is perhaps premature to suggest on the basis of the few published species and various others which I have examined that those groups whose present-day habits would lead them to such localities are better represented in amber.

On the other hand, small or weak-bodied insects are most abundantly represented, particularly those whose habits would lead them

FIG. 2. Leptid fly, probably *Leptis fascinatoris* Meunier, in Baltic Amber. Magnified six diameters.

into the forests. This is perhaps best illustrated by the amber ant-fauna which was first carefully studied by Mayr and more recently and exhaustively by Wheeler. Thus, of the four subfamilies of ants, the most primitive, the Ponerinae, include at the present time mainly terrestrial or subterranean species, and although one tenth of the amber species belong to this group, less than one one-hundredth of the specimens are Ponerinae. We may very plausibly account for this discrepancy by the random trapping of a variety of stray individuals that ventured upon the tree-trunks. The subfamily Camponotinae includes at the present day many dominant, characteristically arboreal ants, and this group is very abundant in amber as the foraging habits of the workers regularly led them to the resin (Fig. 3). The great abundance of particular species is also nicely illustrated by the ants. Thus, two species of Iridomyrmex are known by 5,248 and 1,289 specimens, respectively, and the occurrence of as many as fifty workers of one species in a single block attests their abundance in the amber forests. Another ant, *Formica flori,* almost indistinguishable from the modern *Formica fusca* of Europe, is known from over 1,300 specimens.

Another group that is well represented is the Parasitic Hymenoptera (Figs. 4 and 12). These have not so far been extensively examined, but from the small number which I have so far been able to study, it is evident that the amber fauna is very rich in these insects, all rather small or weak-bodied and abundant at the present time in forests.

As has already been mentioned in connection with the ants, some species of insects have persisted from the Oligocene amber to the present day with so little change that the two forms at each end of the series might almost be considered as representatives of a

FIG. 3. A worker ant, Prenolepis sp., in Baltic Amber. Magnified 15 diameters.

FIG 4. Parasitic Hymenopteron, Phygadeuon (*s. lat.*) *sp.* in Baltic Amber. Magnified 10 diameters.

single species. This is by no means true in general, however, and it is quite evident that evolution has not assumed the same gait in all cases. Certain dominant species, like the Formica referred to, have remained stationary, while other less abundant ones have no close relatives so far as we know in the modern fauna. Of course, very little is known of the living fauna of many parts of the world, and, as has already happened in several cases, we may expect a number of supposedly extinct Oligocene types to be found alive, if not flourishing Nevertheless, it is interesting to note in connection with the questioned importance of natural selection in evolution that it is certain dominant types, presumably well adjusted to their environment, that have seen little change during the lapse of Tertiary time.

This is seen more clearly if we compare the extant genera with the extinct ones known from amber. For this purpose it is convenient to refer again to the ants, a recent group, and to the caddis-flies, a much older one, which, as we have already said, appeared in the middle Mesozoic (Liassic). In a very fine account of the amber caddis-flies (Fig. 5) Ulmer found that slightly less than half of the genera (46.4 per cent.) were extinct, and Wheeler found almost the same proportion (44 per cent.) of extinct genera among the ants. The close agreement in these two diverse groups is surprising, especially in view of the fact that my own investigation of the Parasitic Hymenoptera, although still incomplete, indicates a

FIG. 5. Caddis fly in Baltic Amber Magnified six diameters

far greater preponderance of living genera. It would be premature, therefore, to make a general statement on a numerical basis. If we compare, however, the living and extinct genera, for example, among the ants, we see that among twenty-four extant genera, known from amber, practically all are common, dominant present-day genera, whereas the closest living relatives of the nineteen extinct genera are so far as can be definitely determined far from dominant types. In other words, the dominant types are quite fixed and stable, whereas their less successful relatives are in an active state of evolution, due, it would appear, to the greater opportunities for natural selection.

Many close similarities between the habits and biological relationships of the amber insects and those of the present time may be inferred from a careful examination and comparison of the fossils.

From his taxonomic study of the caddis-flies, for example, Ulmer has been able to show that the terrain occupied by the forests of amber-producing pines was highly mountainous, as a large proportion of the species belong to recent genera known to develop in rushing mountain streams, while a far smaller number inhabit quiet water.

There are a number of insects of diverse sorts which at the present time make their abode only in the nests of ants. One entire family of beetles, the Paussidae, have such habits, and the occurrence of several genera of typical paussids in amber leaves no

FIG. 6. Worker ant of the common Baltic Amber species, *Lasius schiefferdeckeri* Mayr, with parasitic mite attached to the hind leg near the base of the tibia. Magnified 15 diameters.

doubt as to the association of these myrmecophiles with ants in the Oligocene. Still more striking is the occurrence of mites on the hind tibia of an amber species of Lasius (Fig. 6). Two worker ants each have a mite attached at exactly the same place. Modern ants of the genus Lasius are similarly infected by large mites of the genus Antennophorus which also attach themselves to the bodies of the worker ants in definite positions, usually on the head. Feeding upon the honey-dew secreted by aphids or plant-lice is a widespread habit among recent ants, and there exist in amber inclusions containing worker ants together with aphids, which they were undoubtedly attending in a similar way.

Many of the familiar tragedies were enacted under the shade of the trees of the amber forest precisely as we see them at the present day. In the block of amber shown in the accompanying photograph (Fig. 7, A) there is imbedded the empty shell of a Syrphid fly, lacking the head, wings and some of the legs. I have no doubt that it was the victim of a spider, of which many kinds are nicely preserved in other pieces of amber (Fig. 7, B).

As you will have noticed, the most minute details and even in some cases the pigmentation are recorded with great fidelity in the amber insects, but as we have already mentioned there are certain defects which render difficult the complete examination of nearly all specimens. In one like that shown in Fig. 8, one side is clearly visible in great detail through the transparent amber, but if we attempt to view it from the opposite side, it is seen that all detail is lost in a whitening of the medium due to water originally oc-

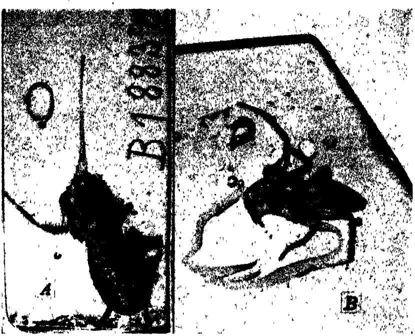


FIG. 7. The Spider and the Fly, in Baltic Amber. A, empty shell of a syrphid fly, with the head, wings and portions of some of the legs missing; B, Spider (Clubiona sp.). Both magnified about seven diameters.

cluded in the resin with the insect. Such defects are quite common. It will be noticed also that the tips of the antennae have been broken off, as they became dry and brittle before the resin had covered them. In other cases air has been included, present as bubbles. In still others, air surrounded parts of the body as a film, which on the hardening of the amber has allowed the matrix to shrink away from the body while still retaining on its surface a swollen and distorted impression of the real object. As the amber is highly refractive, the apparent form of such filmed parts is very deceptive. Other defects in the form of streaks and stream-like lines are often noticeable, as in the case of the spider shown previously. These are due to diffraction caused either by actual movements of the trapped insect through the surface film of the resin, or by shrinkage in the process of drying.

Small or minute insects are frequently preserved in almost perfect condition, due no doubt to the rapidity with which they were imbedded in the resin and to the greater readiness with which the air and water introduced with them was dissipated. Their beautiful preservation is well illustrated by the accompanying photographs of two fungus-gnats (Fig. 9), minute flies belonging to the order Diptera.

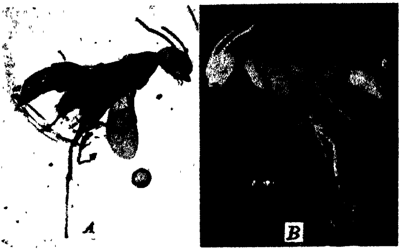


FIG. 8. Ampulicid Wasp in Baltic Amber. Two views of the same specimen from opposite sides to show the fine preservation of details on the right side (A) and their concealment on the left side (B) by a clouding due to moisture included at the time the insect was entrapped.

As already mentioned, several specimens often occur in the same lump of amber, which indicates positively not only that they were contemporaneous, but that all actually visited the particular tree from which the resin came. When different species are thus associated this enables us to relate them as to space and time, irrespective of the period during which amber may have been formed or the area over which the forests extended. The beetle shown in Fig.

FIG. 9. Two fungus-gnats (Mycetophilidae) in Baltic Amber. A. Sciara sp.; B. Macrocera sp.

FIG 10. Small Cistelid beetle, embedded in the same block of amber with an ant, which is shown only indistinctly in the photograph.

10 is thus included in the same block with an ant that is not visible in the photograph, and the two insects in Fig. 12, B are both clearly shown in a single photograph.

Soft-bodied objects are also sometimes well preserved, like the succulent ant pupae here illustrated (Fig 11, B). They belong to one of the very abundant amber ants, *Iridomyrmex geinitzi* Mayr.

A few other amber deposits are known from other parts of the world, and they have yielded also a number of insects, but nothing comparable to the rich and varied fauna of the Baltic amber. Sicilian amber, of middle Miocene age, is the most important of these. Quite recently a fauna of insects and some other Arthropods has been discovered in Burmese amber which is of great interest. These deposits may be Miocene, or perhaps older.

From a technical standpoint, it is disappointing to pass from amber fossils to petrified ones, of which several exceedingly rich deposits of Miocene age are known. The distinction is not so clear as might be taken from this statement, however Amber insects are really highly metamorphosed, due to excessive dehydration and partial carbonization, as is evident if we remove the amber by means of a solvent and observe the hopelessly brittle and powdery nature of the inclusions. The "petrified" Miocene insect-remains are imbedded in finely laminated shales which readily split into layers of paper-like thinness, disclosing the insects flattened out and imbedded between adjacent layers. Thus enclosed in true rock, the remains still retain to some extent their organic composition, although highly carbonized (Fig. 13). Consequently the color pattern is often well preserved and even the metallic color of certain kinds, due in life to diffraction by the superficial layers of the chitinous body-wall, is still evident. Microscopic examination is possible and shows many details of structure.

These Miocene deposits are known mainly from three places, one

at Radoboj in Croatia (lower Miocene), another at Florissant, Colorado (probably middle Miocene), and the third at Oeningen, Bavaria (upper Miocene). Of these, the Florissant deposits have been most exhaustively studied, first by Scudder and more recently by Cockerell, who has not only intensively collected and examined this fauna himself, but who has also persuaded a few other entomologists to devote some attention to it. There are also extensive plant remains, mainly leaves, in the Florissant shales and these have been studied by Lesquereux and Cockerell.

The fossils are found in what was an old lake bed, where they were entombed in material formed by volcanic dust rapidly settling in the waters of the lake. As the chitinous exoskeleton of insects rapidly disintegrates in water, it seems probable that the cement-like character of the dust was an important factor in producing the large numbers of finely preserved specimens.

The general composition of the Florissant fauna is very much like that of the amber so far as its relations to modern insect life is concerned. However, on account of the less perfect preservation, it is more difficult to locate the species definitely in genera, and in the absence of many details there is a tendency to place doubtful species in modern genera from which some of them are probably distinct. With this in mind, it is likely that the smaller number of extinct genera at Florissant compared to Baltic amber is not so striking as would appear from an actual catalogue. Nevertheless, there are fewer extinct genera at Florissant than in the

FIG. 11. An ant and ant-pupae in Baltic Amber. A. Worker of *Iridomyrmex oblongiceps* Wheeler; B. Pupae of workers of *Iridomyrmex geinitzi* Mayr.

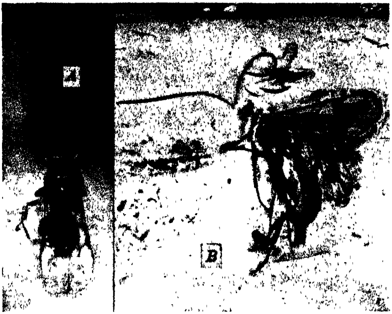


FIG. 12. Two species of Parasitic Hymenoptera in Baltic Amber. A, *Prodinapsis succinalis* Brues; B, Tryphon (s. lat.) sp. with a small midge in the amber just above.

amber, and the fauna in some groups at least has a typically North American aspect. This opinion has been expressed by Wickham, who has studied the beetles with great care, enumerating over 500 species. My own studies of the Parasitic Hymenoptera of Florissant based on 125 species, to which some have since been added by Cockerell, show the same small proportion of extinct genera, but do not suggest that the Florissant fauna appears to be actually ancestral to that of present-day North America.

As with the amber insects, many biological relations may be inferred or surmised from a study of the Florissant fossils. An interesting discovery is the finding of several species of Glossina, the well-known tsetse-flies, now confined to the African continent. The first was found by Scudder, who regarded it as a bot-fly, but its rediscovery together with three other species by Cockerell enabled him to determine without the slightest question that true tsetse-flies occurred in Colorado during the Miocene. As these flies now carry the trypanosomes of human sleeping sickness and of several fatal diseases of large mammals it needs no great reach of the imagination to suppose that these Miocene flies may have been instrumental in causing the extinction of certain large mammals formerly abundant in North America. As a matter of fact such a

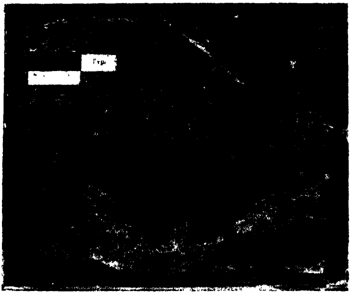


FIG. 13. Butterfly, *Prodryas persephone* Scudder, from the Miocene shales at Florissant, Colorado.

theory previously expressed by Osborn as a possible reason becomes a plausible one after the discovery of the tsetse-flies.

With so many opportunities in a little worked field it is surprising that the study of fossil insects has received such scant attention. Perhaps as the zoologist finds his researches into the activities of living animals increasingly hampered by the well-meaning anti-vivisectionists, he may later more profitably turn his attention to grinding sections of petrified insects, or to removing the amber from long extinct species with boiling turpentine. At any rate this occupation might furnish a harmless vent for his most vicious instincts.

THE ORIGINS OF THE CONCEPTION OF ISOTOPES[1]

By Professor FREDERICK SODDY, M.A., F.R.S.
UNIVERSITY OF OXFORD

ONE of the most important consequences of the study of the chemistry of the products of radioactive change has been the discovery of isotopes and the interpretation in consequence of the Periodic Law in terms of modern views of atomic structure. It is one of the few fields in the vast borderland between physics and chemistry, overrun of recent years by an advancing swarm of mathematicians and physicists, armed with all sorts of new-fangled weapons, in which the invaders have found the chemist already in possession. The broad highways they have hewn thereto are already dusty with the tread of pilgrims, and are being watered by the tears of candidates for "Honors." But the somewhat intricate by-ways through which the chemist first found his way into this virgin territory, and the views on the road before it was in sight, may still preserve something of their pristine interest.

The word *isotope* signifies "the same place," in allusion to isotopes occupying the same place in the Periodic Table. Before this word of theoretical meaning was coined, isotopes were experimentally well known as elements non-separable by chemical methods and completely identical in their whole chemical character. The analysis of the constituents of matter, to which we were born and brought up to regard as the most searching and fundamental, is an analysis by means of its chemical properties Although, later, a new and even more powerful method, spectroscopic analysis, was developed, it merely dotted the *i*'s and crossed the *t*'s of chemical analysis, filled in a few vacant places in the Periodic Law, and handed over the newcomers to the chemist to classify along with the rest of the eighty or so "foundation stones" of which he supposed the material universe to be built up. Then, with the close of the last century, another new method, radioactive analysis, was developed, which is applicable of course only to the radio-elements—that is, to the elements uranium and thorium and the thirty-four, as we now know, successive unstable products of their spontaneous disintegration. Each of these possesses a definite radioactive character;

[1] Address delivered before the Royal Institution of Great Britain, May 4, 1923.

it is produced from one and changes into another element, and, in both changes, rays characteristic of the two substances are expelled, which are as fine a hall-mark of their identity as any of the "tests" of chemical analysis. But radioactive character, unlike spectroscopic character, is completely independent of chemical character. The latter might be called "existence properties," whereas the radioactive character is that attending the explosion of the atom which terminates the existence of the element as such. It provided the necessary independent method of analysis capable for the first time of distinguishing between elements identical chemically and occupying the same place in the Periodic Table—*i e*, between isotopes.

The Earlier Chapter of Radio-Chemistry

Not a hint of this, however, was afforded by the earlier chapter of radio-chemistry. On the contrary no development could appear more normal. Just as rubidium, thallium, etc., were detected by the spectroscope before anything of their chemistry was known, so radium was detected in pitchblende by its radioactivity in concentration thousands of times less than is necessary to show a single line of its spectrum. But with more concentrated preparations a new spectrum *was* discovered, and then a new element, which was found to possess a chemical character entirely new and sufficing for its separation in the pure state from all other elements As in the case of the elements discovered by the spectroscope, radium was found to occupy a place, hitherto vacant, in the Periodic Table. But as it happened radium is exceptional in this Its chemical character was quite normal, and indeed could have been largely predicted beforehand for the missing element occupying this place. The development of the subject showed it to be but one of some thirty-four radio-elements formed from uranium and thorium. But there are not thirty-four vacant places in the Periodic Table to accommodate them.

Meta-Elements

So far as I am aware, there is no anticipation, prior to the systematic study of the chemistry of the radio-elements, of the idea that there may exist different elements with absolutely identical chemical character. Sir William Crookes, it is true, once thought, though the idea has not survived more extended examination, that the properties of the elements, as we know them, might be a mean value, and that the individual atoms composing the element might differ in weight and chemical character continuously on either side of this mean. If so, more refined methods might serve to resolve the element into a collection of what he termed "Meta-Elements,"

possessing the main character of the original, but differing from one another to a slight extent. Misled by the phosphorescence spectra, which are now known to be characteristic of mixtures rather than chemically homogeneous substances, he thought at one time that he had been successful in so resolving yttrium. But the present idea that elements may exist, absolutely the same in chemical nature and yet absolutely different in other properties, such as radioactivity and atomic weight, is totally distinct from this.

The Experimental Method that First revealed Isotopes

I venture to think that no more elegant extension of our methods of gaining new knowledge has ever been obtained than that which, in due course, was to reveal the existence of isotopes. The original observations, upon which the theory of atomic disintegration was first founded, were that thorium is continuously producing a new radioactive substance, thorium X, separable from it by precipitation with ammonia, but not with other precipitants, and, after separation, continuously re-forming again. The thorium X was short-lived, and changed again into a gas, the thorium emanation, for which the name thoron has recently been proposed, which was even shorter-lived and changed again to a solid, the "excited activity," now known as the active deposit, which again went through further changes. The rays resulted from these successive changes, α-rays in the first, and α-, β- and γ-rays in the last changes. Below is the first part of the thorium disintegration series as it appeared to Sir Ernest Rutherford and myself in 1903:

$$\text{Thorium} \xrightarrow{\alpha} \text{Thorium X} \xrightarrow{\alpha} \text{Thoron} \xrightarrow{\alpha} \text{etc.}$$

In 1905 Sir William Ramsay and O. Hahn were engaged in extracting radium from thorianite, a new Ceylon mineral containing both uranium and thorium in important quantities. The radium was separated with the barium, and the chlorides fractionated in the usual way. They found a new radio-element to be present, and to be separated from the radium with the barium. It proved to be the direct parent of thorium X, and intermediate in the series between the latter and thorium, and they called it radiothorium. In spite of this easy and apparently straightforward separation, the experience of a number of chemists showed that something remained to be explained, for it was found to be difficult to the verge of impossibility to separate radiothorium from thorium. Ramsay and Hahn had in fact "separated" isotopes in 1905, for radiothorium and thorium are isotopes. Yet further work has shown the two to be so alike that no separation by chemical means is possible!

Then in 1907, along with the radium which had been separated from thorianite, Hahn discovered another new radio-element, mesothorium, the direct parent of radiothorium and intermediate between it and thorium. In the next year he showed that mesothorium consists of two successive products—the first, the direct product of thorium, mesothorium 1, being practically rayless and generating a short-lived product, mesothorium 2, giving powerful β- and γ-rays.

This resolved the mystery, and one can not do better than to quote the words of McCoy and Ross (*J. Amer. Chem. Soc.*, 1907, 29, 1709):

"Our experiments strongly indicate that radiothorium is entirely inseparable from thorium by chemical processes. . . . The isolation of radiothorium from thorianite and from pure thorium nitrate . . . may have been accomplished by the separation of mesothorium, which in time changed spontaneously into radiothorium."

Thus the radiothorium separated from the mineral thorianite by Ramsay and Hahn was not the radiothorium *in the mineral*, but that subsequently produced from the easily separated mesothorium, after it had been removed from the thorium. If they had fractionated the radium-mesothorium-barium mixture at once they would not have discovered radiothorium. The lapse of time after the separation of the mesothorium is essential. Nowadays many non-separable radioelements are, like radiothorium, "grown" from their separable parents. Thus radium D, an isotope of lead, is grown from the radium emanation (radon) although it can not be separated from the mineral, which always contains lead in quantity.

The first part of the thorium series now runs:[2]

$$\underset{2.10^{10}\text{ years}}{\text{Thorium}} \xrightarrow{\alpha} \underset{9.67\text{ years}}{\text{Mesothorium 1}} \rightarrow \underset{8.9\text{ hours}}{\text{Mesothorium 2}} \xrightarrow{\beta}$$

$$\underset{2.91\text{ years}}{\text{Radiothorium}} \xrightarrow{\alpha} \underset{5.25\text{ days}}{\text{Thorium X}} \xrightarrow{\alpha} \underset{78\text{ seconds}}{\text{Emanation}} \xrightarrow{\alpha} \text{etc.}$$

In this series thorium and radiothorium and mesothorium and thorium X are two pairs of isotopes. If we represent the successive products by balls of different colors to indicate their chemical character, isotopes being of the same color, chemical analysis will sort the balls into their different colors, and the lapse of time will cause some of the colors to change. The ball representing mesothorium will in time turn into that representing radiothorium, so

[2] The periods shown in the second line are the periods of average life of the successive products. These are 1.443 times the period required for one half of the element to change.

that the latter, before indistinguishable from thorium, becomes known as a separate individual.

The Isotopes of Uranium

It will be noted that the method of separating isotopes depends upon their being alternate rather than successive in the series. If radiothorium had been the direct product of thorium, the two would never have been separated to this day. The changes of chemical character are, as we shall later see, intimately connected with the electric charges on the α- and β-particles expelled. For successive products to have the same character no rays, or at least no charged particles, must be expelled. It is always as well—and no subject illustrates the point better than that of isotopes—to reflect not only upon what our methods are able to reveal, but also upon what they can not reveal.

At first it seemed as if uranium itself was a case of successive isotopes. Boltwood in 1908 proved from his study of the relative activities of the successive products giving α-rays in minerals, that whereas all of them, except uranium, gave off only one α-particle per atom disintegrating, uranium gave off two. By direct observation with the scintillation method it was proved that the two α-particles from uranium are *not* simultaneously expelled, and later it was shown that they possess different velocities. If the slower comes from uranium itself (uranium I), the period of which is known to be 6.10^9 years, the swifter must come from the isotope (uranium II), and its period must be some three million years. This is an example of isotopes being revealed by difference of radioactive nature simply, though no other evidence of their separate existences is available. Owing to the long periods of the α-ray giving members of the early part of the uranium series, it has been much more difficult to unravel than the thorium series. As a result of researches too numerous to detail, it has been concluded that the main series is almost entirely analogous to the thorium series, and runs:

$$\underset{6.10^9\text{ years}}{\text{Uranium I}} \xrightarrow{\alpha} \underset{35.5\text{ days}}{\text{Uranium X}_1} \xrightarrow{\beta} \underset{1.65\text{ minutes}}{\text{Uranium X}_2} \xrightarrow{\beta}$$

$$\underset{3.10^6\text{ years}}{\text{Uranium II}} \xrightarrow{\alpha} \underset{10^5\text{ years}}{\text{Ionium}} \xrightarrow{\alpha} \underset{2440\text{ years}}{\text{Radium}} \xrightarrow{\alpha} \underset{5.55\text{ days}}{\text{Radon}} \xrightarrow{\alpha} \text{etc.}$$

Though two short-lived products probably intervene between the two uraniums, analogous to the two mesothoriums between thorium and radiothorium, the relation of their period to that of their product, uranium II, is so hopelessly unfavorable that there is no hope

of ever being able to put the separate existence of uranium II into evidence in the same way as was done for radiothorium. For all *practical* purposes the two uraniums are as non-separable by this method as if they were actually successive products. I spent many years, before this part of the series was at all well known, looking for the product of uranium X, and separated this constituent from 50 kilograms of uranium nitrate repeatedly in the attempt. I was looking for a growth of α-rays concomitantly with the decay of the β-rays of the uranium X. If the product had been ionium, as at first thought (U I $\xrightarrow{\alpha}$ U II $\xrightarrow{\alpha}$ U X $\xrightarrow{\beta}$ Io $\xrightarrow{\alpha}$), it should have been just possible to detect it. But since it is the thirty times longer-lived uranium II, the attempt is hopeless, especially as uranium X and ionium are isotopes, and therefore the uranium X separated must always possess a certain initial α-activity due to ionium.

The Absolute Chemical Identity of Isotopes and its Implications

The years 1908–1910 were productive of many prolonged and serious efforts to separate isotopes by chemical means. In 1908 Boltwood discovered ionium, and showed that it resembled thorium. Keetman, who with Marckwald discovered ionium independently, tried twelve good methods, all known to be effective, in the purification of thorium in the attempt to separate the ionium from thorium, completely without success. Auer von Welsbach, on a technical scale, separated the ionium and thorium from 30 tons of pitchblende, and tried fresh methods in the hope of separating them, but failed. It was with this preparation that Exner and Haschek tried without success to find the ionium spectrum, and Russell and Rossi confirmed their result, that the spectrum was that of pure thorium. When later I had determined beyond doubt, from measurements of the rate of growth of radium from uranium, that the period of ionium was 100,000 years, and that Welsbach's preparation must have been approximately 30 per cent. ionium and 70 per cent. thorium by weight, it followed that the spectra of isotopes must, like their chemical character, also be identical. The difference, if any exists, is almost beyond the limit of detection by the most powerful methods.

Similarly, the chemical identity of radium D and lead was established as a consequence of very prolonged and refined chemical examination. Paneth and Hevesy established upon this their well-known method of using radioactive isotopes as indicators for elements in too small quantity to be dealt with except by such methods. On the principle that wherever the radioactive element

is there will its inactive isotope be also, provided that they have once been properly mixed, many difficult or uncertain chemical analyses may be converted into simple radioactive ones.

In 1909 Strömholm and Svedberg made what was probably the first attempt to fit a part of the disintegration series into the Periodic Table, and although the effort in itself was in an important respect erroneous, in their paper is to be found the first anticipation that the chemical non-separability found for certain pairs and groups of radio-elements may also apply to the non-radioactive elements. Remarking on the fact that there are three parallel and independent radioactive series, they suppose this to proceed down through the Periodic Table, "but that always the three elements of the different genetic series, which thus together occupy one place in the periodic system, are so alike that they always occur together, and also have not been able to be appreciably separated in the laboratory." They point out also this idea would explain the exceptions to the periodic system "if the elements of the scheme were mixtures of several homogeneous elements of similar but not completely identical atomic weight."

In the next year I arrived independently, and without in the least postulating any continuance of the genetic series beyond the radio-elements, at a similar view. Marckwald and I found independently that mesothorium I was chemically similar to radium, a fact undoubtedly known to Hahn and those engaged in the technical extraction of mesothorium, but kept secret. It was known from some work of Boltwood that precipitating barium sulphate in a solution containing mesothorium removes it, but it was thought that the action of the barium sulphate was similar to that in removing uranium X, for which it had long been used—namely, a simple adsorption. I was surprised to find it absolutely different. The removal of the barium from the mesothorium, as from radium, could only be accomplished by the fractional crystallization of the chlorides. In this fractionation the radium and mesothorium remained together and behaved as a single element. Within the limit of error of the most careful radioactive measurements, there was no change in the relative proportion of the two elements at the end of the process, from that in which they exist in the original mineral. Chemistry has many cases of elements similar in chemical character, but nothing approaching this. For we know, beforehand, that we are dealing with a mixture of two substances, and can estimate accurately the proportion of each individual. Yet to all chemical operations they behave as a single substance. The differences of atomic weight are considerable, two units in the cases of mesothorium and radium, and of ionium and thorium, and four units

in that of radiothorium and thorium. It was certain that if isotopes existed in the case of the ordinary chemical elements, the absence of a second radioactive nature independent of the chemical nature would make it impossible for them to have been recognized. Hence the implication followed that any supposed element may be a mixture of several chemical identities of different atomic weight, and any atomic weight might be merely a mean number (Ann. Reports, Chem Soc., 1910, 286). There is an element of tragedy in this. The life-time labors of the chemists who, since the time of Stas, have devoted themselves to the exact determination of atomic weight, appear to have as little theoretical interest now, as if you sought to determine the average weight of a collection of beer bottles, all exactly alike, but not all quite full.

The Radio-Elements and the Periodic Law

The years from 1911–1913 were crowded with important advances, and to do the exact history justice would take an undue share of the available time. In 1911 the chemistry of most of the α-ray giving members were sufficiently known for it to be seen that the expulsion of the α-particle caused the element expelling it to move from the place it occupied in the Periodic Table to the next place but one to it in the direction of diminishing mass.

At this time the chemistry of the post-emanation members had scarcely been studied, though von Lerch, from electrochemical researches, had put forward the rule that the successive products are each electrochemically "nobler" than the last, a rule which describes well enough the electrochemical behavior of the first three —the A to C members, as they are called. Then as a result of the experiments of Schrader and Russell, it was found that their volatility was much affected by chemical treatment and by the atmosphere in which they were volatilized. Thus, in hydrogen, radium C volatilizes at as low a temperature as 360° C., though, in air, a temperature of 1200° C. is necessary. This clearly indicated the possibility that even these excessively ephemeral elements have a definite chemical character. Hevesy showed, by electrochemical methods, that the three B-members are identical in properties among themselves, and also the three C-members.

But the work, which, more than anything else, served to reveal as in a flash the simple and sweeping generalization which covers the evolution of the radioactive elements was that of A. Fleck in my laboratory in Glasgow. He studied the chemistry of the various members, still uncharacterized, from the definite point of view of ascertaining to which element each most closely approximated in chemical character, and then whether it was separable from that

element or not. In addition to confirming more rigorously many conclusions already reached, he proved that mesothorium 2 was non-separable from actinium, the three B-members from lead, like radium D, and the three C-members and radium E from bismuth.

Hevesy and Russell—the first with regard to the valency of the radio-elements and the second with regard to the positions they occupy in the Periodic Table—published early in 1913 statements of the full law underlying radioactive evolution, but only in part correct. Within a month K. Fajans in Carlsruhe published the scheme correct and complete, including the complicated branchings that occur at the C-members. In a paper, amplifying and amending Russell's scheme, I arrived independently at the same place as Fajans. Each α-ray expelled causes a shift of two places in the Periodic Table in the direction of diminishing mass, and each β-ray a shift of one place in the opposite direction. In its present form the scheme is shown in the figure. The chief uncertainty remaining is whether the actinium branch starts from uranium II, as shown in the figure for convenience, or from uranium I, or even from a third independent isotope of uranium. So that the atomic weights shown for the actinium series are purely provisional.

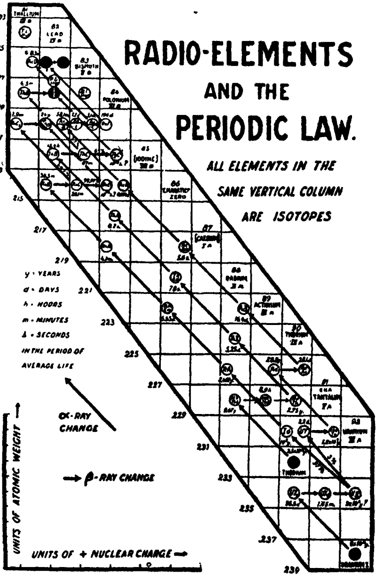
By the consistent application of the two rules mentioned the members found to be non-separable from one another fall in the same place in the Periodic Table. The chemical character has nothing to do with the radioactivity, nor with the series to which the element belongs, nor with its atomic weight. It depends upon a number, now called the atomic number, shown at the top of the place in the figure.

Before passing on to this, the chief practical consequences of the generalization may be briefly enumerated.

(1) Of the members still uncharacterized, the A and C′ members must be the isotopes of polonium (radium F), and radium C_2 (now called radium C″), actinium D and thorium D must be isotopes of thallium. Fleck at once verified these predictions as regards radium A, actinium D and thorium D.

(2) Uranium X, like mesothorium, must consist of two successive β-ray giving products, intermediate between the two uraniums. Fajans and Gohring at once succeeded in separating from "uranium X" a very short-lived product, uranium X_2, giving the more penetrating of the two types of β-ray expelled, the uranium X_1 giving the less penetrating β-rays.

(3) The parent of actinium in the IIIrd family must be an isotope of radium, if actinium is formed in a β-ray change—a conclusion I at once experimentally disproved—*or* it must be an isotope of uranium X_2, in the Vth family, if actinium is formed in an α-ray


RADIO-ELEMENTS
AND THE
PERIODIC LAW.
ALL ELEMENTS IN THE
SAME VERTICAL COLUMN
ARE ISOTOPES
y - YEARS
d - DAYS
h - HOURS
m - MINUTES
s - SECONDS
IN THE PERIOD OF
AVERAGE LIFE
α-RAY
CHANGE
β-RAY CHANGE
UNITS OF ATOMIC WEIGHT
UNITS OF + NUCLEAR CHARGE
THALLIUM
LEAD
BISMUTH
POLONIUM
EMANATION
ZERO
RADIUM
ACTINIUM
THORIUM
EKA
TANTALUM
URANIUM
203
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change. This was proved by Cranston and myself, and the name "eka-tantalum" given to the new element, and by Hahn and Meitner, who named it protoactinium. It is linked to uranium through uranium Y, a branch member discovered by Antonoff in 1911, and suspected to be in the actinium series.

Protoactinium, to give it Hahn and Meitner's name, has been shown by them to give α-rays, and to be chemically so like tantalum that hitherto it has not been separated from it. Its period is about 17,000 years, and from this it may be calculated that there is about one fifth as much of it by weight in minerals as there is of radium. This may be sufficient to enable it to be isolated and for its spectrum, atomic weight and chemical character to be ascertained. The branch series runs:

$$\underset{\text{VI}}{\text{U}} \xrightarrow{\alpha} \underset{\text{IV}}{\text{UY}} \xrightarrow{\beta} \underset{\text{V}}{\text{Pa}} \xrightarrow{\alpha} \underset{\text{III}}{\text{Ac}} \xrightarrow{\alpha} \underset{\text{IV}}{\text{RaAc}} \xrightarrow{\alpha} \underset{\text{II}}{\text{AcX}} \rightarrow \underset{\text{O}}{\text{An}} \xrightarrow{\alpha} \text{etc.}$$

in which the figures in the second line refer to the family in the Periodic Table to which the element belongs

(4) All the ultimate products in all branches are isotopes of lead. The atomic weight of the two products of thorium are both 208, and of the major branch of uranium 206. As is well known this had only to be tested to be proved correct. The atomic weight of the lead from the purest thorium minerals is as high as 207.9, and of that from the purest uranium minerals 206. The spectra of these isotopes, but for the possible infinitesimal difference already alluded to, are identical. But the densities are proportional to their atomic weights. This was a very simple prediction I made, before testing it, from the theoretical views about to be dealt with.

The Theoretical Interpretation of Isotopes

The results on the theoretical side were no less definite and important, and isotopes found a ready explanation on the nuclear theory of atomic structure put forward in a tentative form by Rutherford in 1911. This theory accounted for the large angles through which occasional α-particles were deflected in their passage through atoms, by the existence of a very minute highly charged nucleus at the centre of the atom, the rest of the atom being occupied by separate charges of opposite sign equal in number to the nuclear charge. For such an atom scattering should be proportional to the square of the nuclear charge. Experiment showed that scattering was approximately proportional to the square of the atomic weight. So that it looked as if, as in the α-particle itself, there existed one unit of nuclear charge to each two units of atomic weight. This would make the nuclear charge of uranium, of atomic weight about 240, 120 +.

Since the α-particle carries two positive charges and the β-particle one negative, the obvious inference from the figure is that the successive places in the Periodic Table correspond with unit difference in the intra-atomic charge. This view, and also that each unit of charge corresponded to two units of mass, had been suggested independently by van der Broek in 1911. At first he tried to stretch the Periodic Table to make it accommodate 120 places. But, in 1913, he pointed out that the experimental results for scattering were completely in accord with his own view (that the number of the place is the same as the intra-atomic charge), *on the existing Periodic Table,* which accommodates only some 90 elements. It would not be inconsistent with his other view (that the nuclei of the heavy elements are made up of helium nuclei) if there were electrons in the nucleus as well as in the outside shell. Thus uranium in the 90th place would have to have, in addition to the 60 helium nuclei in its nucleus to account for its weight, 30 electrons, to account for its charge of 90 +.

The existence of electrons as well as positive charges in the atomic nucleus was also postulated by Bohr to explain the emission of *β-rays,* for on his theory the electrons in the external shell form a stable configuration and could only be dislodged by the expenditure of work.

The Periodic Law generalization practically settled this question. β-ray changes are no less transmutational than α-ray changes, and are sharply to be distinguished from the numerous processes, such as friction, chemical change, action of ultra-violet light and incandescence, during which electrons are detached from atoms. The effect on the chemical character produced by the expulsion of one α-particle is exactly undone by the expulsion of two β-particles, and the product becomes isotopic with the original parent. This means that both α- and β-particles must be expelled from the nucleus, and that isotopes are elements the atoms of which have the same *nett* nuclear charge—*i.e.,* the same excess number of positive over negative charges in the nucleus, but different numbers of positives and negatives reckoned separately. For such systems the electronic shell would be identical, and so the identity of the chemical and spectroscopic character is explained. Also the atomic volume is the same—that is, the density must be proportional to the atomic weight.

We were able to get an interesting confirmation of this view. In the change of uranium X_1 to uranium II two electrons are lost as β-rays. In the oxidation of a uranous salt to a uranic or uranyl salt two electrons are also lost. If these come from the same region of the atom as the β-particles, then uranous salts, so long as their

valency does not change, should be like uranium X_1, chemically non-separable from thorium. Fleck, trying this, found great similarity in chemical properties between uranous salts and thorium, but not identity. He was able to separate them by chemical methods without changing the valency of the uranous salt.

The great merit of the nuclear atom from the chemist's point of view was that it afforded for the first time a clear picture of the difference between a chemical and a transmutational (or radioactive) change. The latter occur in the nucleus and are irreversible. The external shell accommodates itself instantly to the change of the nucleus. But any change suffered by the external shell (chemical change) has no effect on the nucleus, which always acts so as to make the external shell conform to one most stable configuration.

The atom is an *imperium in imperio*, and like most such systems is very conservative and resistant to change. The electrons in the shell, that govern almost all the atomic properties, except mass and radioactivity, are in turn but the bureaucratic instruments of the real government, which is the intensely charged central nucleus. The transmutation of atoms, as of social systems, is alike impossible because the apparent government is not the real government. Rutherford's experiments, on the bombardment of atoms by α-particles, show that only about one out of a hundred thousand of the latter in passing through hydrogen ever hit a hydrogen nucleus, and the proportion of hits to misses is something like one in one thousand millions. In politics, contrasting the number of missiles hurled with the results achieved, the shooting seems even worse. It is only when the atomic or social systems break up or break down that we learn even of the existence of their real internal constitution.

PETRUS BONUS AND SUPPOSED CHEMICAL FORGERIES

By Professor JOHN MAXSON STILLMAN
STANFORD UNIVERSITY

STUDENTS who have followed the history of early chemistry will remember that the results of critical research during the past half century have thrown grave doubts upon the authenticity of a number of medieval authorities on chemistry or alchemy.[1] Notable among these are alchemical treatises ascribed to Thomas Aquinas, prominent ecclesiastic who died in 1274 A. D., and to whom Professor Karl Schmieder in his "Geschichte der Alchemie" (1832) attributes six treatises on alchemy, and cites as many more titles on the authority of Borellus; Albertus Magnus (died 1282) to whom Schmieder attributes ten treatises on chemistry of which, one only, on minerals, is now accepted as genuine; Roger Bacon (died 1292), for whom Schmieder lists fifteen articles, nearly all of which are considered fraudulent. Two other of the principal authorities of the alchemists were Raymond Lully and Arnald of Villanova. Schmieder lists twenty-five titles to Lully and twenty to Arnald. Yet B. Haureau, the scholarly biographer of Lully and Arnald, presents good reasons for believing that all attributed to Lully are forgeries of later date, and for doubting that any alchemical writings attributed to Arnald are authentic, and other modern critics have come to the same conclusion. Lullus died in 1315 and Arnald about 1312. Generally speaking, the disbelief in the authenticity of these treatises has come from internal evidence presented by the treatises themselves, either in allusions made to persons or events later than the twelfth or early thirteenth centuries, or from discrepancies in subject-matter or style of writing between these treatises and the unquestioned writings of these prominent scholars.

The fourteenth and fifteenth centuries were periods when alchemical literature was very generally issued anonymously or under false names. Reason for this existed in the attitude of church and civil authorities toward alchemists. As these were generally believed to be counterfeiters and makers of false gold and silver, and sometimes to be in league with evil spirits, many edicts were issued against practicing alchemy and even the possession of alchemical

[1] Compare the writer's article, "Falsifications in the history of early chemistry," SCIENTIFIC MONTHLY, XIV, p. 560.

books and apparatus. A common custom, therefore, of those who nevertheless wrote on alchemy was to credit their works to some past author of established reputation in some natural science, and evidently these manuscripts would have a greater circulation if this author were a person of distinction.

By the beginning of the 16th century, when book-printing became general, great numbers of these manuscripts were printed, either separately or in collections, and here again unscrupulous publishers sometimes attached prominent names as authors of anonymous manuscripts. It can readily be understood that this flood of printed works presented serious problems as to dates of writing and as to authorship, which the scholarship of the period was in no position to solve. With some sporadic doubts and exceptions, these manuscripts were accepted at their alleged valuation, and only on the basis of much later critical comparisons were other conclusions often adopted.

Earlier historians of chemistry, Lenglet du Fresnoy, Gmelin, Schmieder, Hoefer and Kopp accepted as genuine the writings on alchemy attributed to Albertus Magnus, Roger Bacon, Lully and Arnald of Villanova, and it is indeed mainly from considerations which have developed during the past half century that the present disbelief in their authenticity has arisen. This conviction has been the result of more accurate knowledge of the life and works of the men, from internal evidence contained in the treatises in question, and from comparisons of the subject matter and style in the works of acknowledged authenticity with the works suspected of interpolation. Any direct evidence from the period of the writing of these suspected writings is in general wanting. Under these conditions, importance attaches to certain circumstantial evidence from a treatise written by an Italian called Petrus Bonus, who wrote an elaborate treatise of some 85,000 or more words on the philosophy of alchemy, in which he treats exhaustively of the reasons for and against the truth of the art and of various theories advanced or maintained in the science. In this lengthy discussion he depends upon the opinions and statements of previous writers, and cites his many authorities frequently and conscientiously. The work bears the date of 1330, and upon the accuracy of this date its value as evidence here depends.

In the text following the preface and just preceding Chapter I of the twenty-five chapters, it is stated (translated):

> Here begins a treatise by Master Petrus Bonus, the Lombard of Ferrara, natural Philosopher, introductory to the Art of Alchemy, composed in the year 1330 from the birth of our Lord Jesus Christ, in the city of Pola of the Province of Istria.

Also, in the closing paragraph of the treatise he says:

This lengthy discussion Master Bonus of Ferrara, simple philosopher (Physicus subtilis), after having solemnly and carefully investigated, sifted, disputed, delimited and strengthened, has collected and arranged, in the year from the birth of Christ 1339,[2] being then a salaried official in Pola of the Province of Istria; in which (treatise) he has inserted that which he has learned of speculative and practical knowledge and the operation of it—defending it moreover and relying on the reputations and reasonings of the ancients and adding reasons of his own. Moreover I ask and adjure all those wise in these things, into whose hands this "Precious New Pearl" may fall, that they communicate the same to all men attentive to this subject, desirous of the art, and that they conceal it from the ignorant and from boys, since they are unworthy.

We have previously written a similar discussion in the City of Cragurius[3] in the year '23, which we destroyed on account of the great excellence of this. Here ends the Preciosa novella Margarita, edited by Master Bonus, the Lombard, natural philosopher of Ferrara, introducing to the Art of Alchemy, composed in the year of our Lord 1330. In the city of Pola in the Province of Istria.

This work of Petrus Bonus enjoyed a considerable popularity after the era of printing began. It was first printed in the form of a condensation, with other works by Lacinius in 1546 at Venice, and later impressions were in 1554 at Nürnberg, 1572 at Basil, 1602 at Mömpelgard, 1608 at Strasbourg, in the collection of works "Theatrum Chemicum" in Strasbourg 1659–61, in Mangetus, Bibliotheca Chemica, Geneva 1702.[4] Examination of the text of the Preciosa Margarita shows that Bonus based his discussion, not upon any recorded experience of his own, but upon a careful and conscientious digest of all authorities known to him. He very systematically cites these authorities to justify his statements, and nearly all these authors he cites several times, and some of them many times. Names of writers upon alchemical philosophy mentioned by Bonus comprise nearly all those whose works were referred to in the encyclopedic works of Vincent of Beauvais, Albertus Magnus, Bartholomaeus Anglicus, and Roger Bacon in the thirteenth century, and notably one important authority later than these—Geber, much cited by Bonus. The name of Geber is mentioned at least forty-one times in the Margarita. Names of authors cited by Bonus are Aristotle, Plato, Hermes, Morienus, Razes, Avicenna, Rosinus, Senior, Lilium, Melvescindus, Alphidius, Haly, Galen, Averroes, Mesue, Democritus, Alexander, Socrates,

[2] Probably a misprint for 1330 in the impression of Mangetus 1702. Whether this persists in all earlier prints is not known to the writer.

[3] Cragurius unidentified by the writer. Could it be a corruption by author or copyist for Cracovia, Cracow?

[4] This is the impression used by the writer.

Empedocles, Albumazar, Moyses, Arislaeus, Calid, Porphyrus, Melissus, Albohaly, besides a long list of names cited from the "Turba Philosophorum," a compilation of alchemical philosophy, of probably the twelfth century, in the form of a dialogue among ancient writers real and imaginary. Some of the above names are known to have been pseudonymous, but at that time they were generally credited and esteemed by writers. With the exception of certain early Egyptian and Greek alchemists, the list of Bonus comprises the popular alchemical philosophers known to the thirteenth century. The references to Geber are to his "Summa Perfectionis Magisterii," his first and principal work, which was supposed to be derived from the Arabian of the true Geber or Djaber of the eighth or ninth century A. D., but appeared after 1300 A. D. and is now known to have been written originally in Latin at about the time it was issued, 1300. Incidentally it is interesting that Bonus refers to Geber at least twice as Geber Hispanus, which is quite in accordance with the modern belief that Geber or Pseudo-Geber, as he is often called, was a Spaniard or Italian, who had studied in Spain.

Especially notable is the fact that Bonus makes no mention of Albertus Magnus, Thomas Aquinas, Roger Bacon, Arnald of Villanova nor Raymond Lully. Considering that in 1330 these authors had been dead for from fifteen to more than fifty years, and the high reputation that these authors enjoyed as alchemical philosophers and operators in the fifteenth and sixteenth centuries, the absence of these names from Bonus's list of authorities, otherwise so comprehensive, certainly demands explanation.

Is the date 1330 for the work of Bonus to be depended on as correct? There is another case of an alchemical writer whose writings were presumably undated and whom early historians of alchemy assigned to an early period, because no references were made by him to the authors in question. This was the writer known as the Monk of Ferrara, Frater Ferrarius or Efferarius.

Olaus Borrichius, in his account of celebrated chemical writers published in 1697, alludes to this man as a foggy or obscure writer, and says that though he discusses the writers of the Turba, Geber, Plato the chemist, and Morienus, he never mentions Villanova nor Lullus and therefore it appears that he must be considered as earlier than those authors. Lenglet du Fresnoy in his "Histoire de la Philosophie Hermetique" (1742) similarly says of the progress of alchemy in Italy: Pierre le Bon (Petrus Bonus) of Lombardy and the Monk Ferrari applied themselves to it about the same time in Italy. The former worked in Pola, maritime city of Venetian Istria, and published a complete treatise on the hermetic

science of which the Calabrian Monk Lacinius has since given a well-finished abstract. We have also the treatise of the Monk Efferari or Ferrari, though the latter is little read by connoisseurs, although in the midst of much obscurity we find some rays of light, but it is necessary to know how to discover them. He is believed to be of the end of the thirteenth or at least of the beginning of the fourteenth century, because while citing Geber, the Turba, and the hermit Morienus, he says not a word of Arnald of Villanova, nor of Raymond Lully, who were nevertheless two great masters who deserved to have been cited, if he had lived later than they.

Karl Schmieder in his "Geschichte der Alchemie" (1832) says of Ferrarius, Efferarius or the monk of Ferrara:

> We know nothing of his personality, and even his epoch can only be inferred from his writings. As in these he cites Geber, Morienus and the Turba of Arislaeus, but alludes to neither Albertus Magnus, Roger Bacon, Arnald nor Lully, he may provisionally be assigned to the years around 1200. Lenglet du Fresnoy places him surely too late—the year 1280.

John Ferguson in his "Bibliotheca Chemica" (1906) lists Ferrarius or Efferarius as "supposed to have flourished about 1200, the date 1280 put forward by Lenglet du Fresnoy being deemed too late. The argument for the date started by Borrichius is that, since he quotes the Turba, Geber and Morienus, but not Arnaldus or Lullius, he must have lived prior to the latter, that is about the beginning of the thirteenth century. I am not sure that this is conclusive." Ferguson states no reasons for this remark.

As it did not occur to the early historians to doubt the authenticity of the many treatises on alchemy attributed to Albertus, Thomas Aquinas, Roger Bacon, Lullus or Arnald, they naturally saw no other explanation of the absence of their names that seemed reasonable. Yet all these historians, in mentioning the work of Petrus Bonus, credit his date of 1330 without noticing apparently that he also while referring to Geber, the Turba, Morienus and many others yet also makes no reference to any of the five authors in question, and according to the same logic should have been assigned to a century earlier.

Schmieder says of Bonus that he was not a clerical, but master of liberal arts, lived at Pola in Istria, where according to his own data he completed the Margarita in the years from 1330 to 1339. He defends alchemy zealously against the doubters of his time, but seems to value but slightly the writings of Arnald and Lullus which were then in circulation, but considers that Geber alone shows the true path, thus allying himself with the Arabians. This is not a correct statement, for Bonus makes no mention whatever of Arnald nor Lully. A fact of importance respecting the correctness of the

date of the Margarita is that according to the results of modern criticism by Berthelot and others, the work of Geber—the Summa—was first issued not earlier than 1300. Indeed, Ernst von Meyer in his "History of Chemistry" (3d English Edition, 1906) states: "The oldest of these—the celebrated Summa Perfectionis Magisterii—was not before the middle of the fourteenth century." The work of Bonus establishes that it was probably somewhat earlier than the middle of the century. The argument by which the historians assign Efferarius to the thirteenth century also is contradicted by this fact, for this author also cites from Geber and therefore could not have been much earlier than Bonus, and he also does not mention Lullus, Arnald, Albertus or Roger Bacon, according to the historians.

On the other hand, it does not seem at all probable that these prominent authors wrote articles on alchemy, and that yet these articles should have all been concealed from the public for from a quarter to half a century before bursting on the alchemical public.

The more plausible explanation is that none of these writings was written at the time of Bonus or of Efferarius This as already stated would be in accord with the tendency of modern criticism that all these alchemical works are forgeries and we may infer that they were issued later than the date 1330.

The question naturally arises why Bonus, writing at a time when alchemical writings were so generally prohibited that nearly all such works were issued either anonymously or under false names and either undated or misdated, should have ventured to describe time and place so specifically. To this it may be said that his work was very different in character from the great majority of alchemical works in that it makes no professions of accomplishment of transmutation, nor does his treatise pretend to give any directions, however obscure, professing to impart clues for such processes. In fact he clearly states that he does not believe that power to lie in the ability of human reason, and can only be achieved through the divine favor. As the prohibitory edicts were directed against alchemists on the supposition that they possessed the power to produce counterfeit gold and silver, and perhaps also because they were in league with evil spirits—Bonus might well have believed that his work was not such as was prohibited under these edicts. His was a purely theoretical discussion of alchemical philosophy. Hoefer in his "Histoire de la Chimie," speaking of the Margarita, says it is filled with theoretical considerations which bear witness to great dialectic ability, but to very little of the spirit of observation.

It would be a satisfaction to have some independent informa-

tion concerning the personality of this Petrus Bonus. The writers who have described his work give no evidence that they know anything of him which is not derived from his own manuscript. Borrichius, Lenglet du Fresnoy, Schmieder, Hoefer and Kopp all make mention of him and briefly characterize his work and accept the date of 1330 as the time of writing. There are two or three other titles of alchemical works ascribed to him, though of less popularity than the Margarita, but they do not seem to have conveyed any further information of the author.

The writer has found but one differing account quoted by John Ferguson in his "Bibliotheca Chemica" among other references. This is from a certain Mazzuchelli in a work published in 1762, "Gli Scrittori d' Italia," who refers to Pietro Antonio Boni, says "he lived in 1494, was a physician skilled in philosophy and took delight in alchemy and wrote Rationes pro Alchemia et contra." If this Mazzuchelli really refers to Petrus Bonus and his "Preciosa Margarita Novella," and his statements were based on fact, we should have to assume that Bonus had antedated his work a century or more, and that even then the alchemical works of Albertus, Lullus and the others were not yet known to him. While we lack reliable knowledge as to the dates of their appearance, it seems hardly credible that they were not at this time known to the chemical public. It seems more reasonable to assume that some other person is referred to or that there is some confused or mistaken identity in Mazzuchelli's reference.

In a recent critical translation into German of Geber's work, Dr. E. Darmstaedter (Die Alchemie der Geber, Berlin, 1922) calls attention to the fact that in the earliest known manuscript in Munich, of the Summa Perfectionis of Geber, attributed to the end of the thirteenth century, the titles of three other works are mentioned, De Investigatione Perfectionis, De Inventione Perfectionis and Liber Fornacum. Darmstaedter adds, "Whether the works known under those titles and here presented in German translation are really by the author of the Summa Perfectionis, or are elaborations of a later period will not be here discussed. This much may be said, that no manuscripts of the books De Inventione and Liber Fornacum are known to me and these writings are found in but few printed works." Darmstaedter also notes that the earliest manuscripts of the "Summa" lack the more elaborate titles, Perfectionis or Perfectionis Magisterii, that occur in later manuscripts and in printed editions.

In this connection it is interesting to observe that Petrus Bonus in his numerous references to Geber cites from his "Summa" under that title only, never mentioning it under a more extended title.

Also when discussing that work he expressly says, "His other work De Inventione Perfectionis which he refers to as preceding this, we have not yet seen."

These facts are in harmony with the authenticity of the date of 1330 as given by Petrus Bonus, and are of interest also as bearing upon the disputed question as to whether the other works besides the "Summa" attributed to Geber are genuine or the elaborations of later writers.

The reasonable assumption on the basis of all present information is that the Margarita was correctly dated, shortly after Geber's "Summa" had appeared, and that at that time the alchemical works attributed to Thomas Aquinas, Albertus Magnus, Roger Bacon, Raymond Lully and Arnald of Villanova were not known to Bonus, because they were not yet written, being forgeries of periods considerably later than the lives of those authors to whom they were ascribed.

AMERICAN TENDENCIES IN GEOGRAPHY

By Professor O. D. VON ENGELN
CORNELL UNIVERSITY

GEOGRAPHY and geographers both are commonly regarded as having an existence beyond the pale To set forth plainly how and why they have come to be thus outlawed is a task of the same difficulty with defining the content of geography. Indeed, the two problems are linked up with each other. Geographers are under a cloud because what should properly comprise the subject-matter of geographic studies is itself involved in mists.

To be sure, distinguished personages of various times have been called geographers. Darwin and von Humboldt would be named in such a list. Analysis of a catalog of worthies, classed as great geographers, would, however, immediately disclose that almost every person included had attained distinction independently of geography per se. Some, it would be found, earned enduring fame because they were great travellers; others were cartographers of note. Certain individuals are remembered because of the literary excellence of their works, others for their assiduous labors in compilation. In each such instance there could be noted "something else again" besides geography to insure the world's acclaim.

There might be a large tolerance of the indicated failure of geography to establish itself as a clearly defined science were it not for the fact that, in America at least, almost any individual who is led to attempt an appraisal of the subject is thereby also made conscious of a discontent with his experience of geography as a study in school. The geography text with its many pictures and diagrams promised much; the actual conning of that text in successive lessons usually proved tiresome and disappointing. There was little enthusiasm for the systematic study of geography while it was being done, and later on in life there developed a realization that in failing to get from geography what it should contain something fundamental in education had been missed. American geographers have not been unaware of this situation and the text-book writers of their number have striven to remedy the difficulty. But despite these endeavors and the changes in the content of the texts and the presentation of the material which have resulted from them, and which should in fairness be counted as advances, instruction in geography from the elementary schools up through the universities is admittedly unsatisfying.

All this is by way of introduction. It is proposed here to inquire why geography has failed to establish itself as a science occupying a clearly defined field and what its defects as a school subject have been and are; then, further, to present the attitude of American students professionally engaged in geography towards the problem and the possible significance of the tendencies now apparent.

The province of geography does not, on review, appear especially difficult of simple definition. It is the science concerned with the description of the earth and its inhabitants. With regard to the first clause of this formulation, the description of the earth, there is no occasion for argument. That business is assigned to geography and to geography only. The existence of geology, physiography, meteorology and oceanography as distinctive fields for study and investigation does not at all detract from geography. These other earth sciences are concerned with the examination and discussion of the origin and nature of particular phenomena; thus of the inner structure and outer form of the earth, of the air which surrounds it and of the water which fills its hollows. These special branches contribute to the subject-matter of geography and recognize that it is their function to do this unreservedly. From geology geography derives facts relating to soils and mineral deposits; through physiography geography is informed of the shape and features of mountain and plain, meteorology provides knowledge and understanding of climate, and oceanography of the disposition of ocean currents and the rise and fall of tides—among other things in each case.

The description of the earth itself, its physical reality, to which these children-sciences of geography dutifully contribute, is a vast task. It involves, to begin with, diffusion of knowledge regarding the distribution of the lands and the seas on the earth and of their particular configurations, first as to absolute position and second in relation to each other. Further, it does not suffice to indicate, merely, that a large island lies in latitude 20° S. and longitude 46° E. off the east coast of Africa; it is necessary that the island should be identified by its name label, Madagascar.

It may be set down, therefore, as a dictum that before the student can make progress in other phases of geographic learning he must have attained an adequate equipment of this fundamental knowledge of locations and name labels. But it is exactly that training more than anything else which he fails to get under the modern system of geographic instruction in American schools. The name-label phase of locational geography was emphasized more a generation or two ago; indeed, it was then carried to absurd extremes. The student, for example, was then required to learn, and

to repeat in alphabetical order, the names of all the counties of the home state. If there had been insisted upon, also, at that time, an equally glib knowledge of the location of each of these counties within the state the training in calling the roll of their names would not have been so altogether futile as it was. The other, and modern, extreme in elementary geographic instruction is marked by the fact that students have been known to enter undergraduate courses in universities uncertain whether North America is a continent or a country.

It should be recognized, and acted upon, that the first steps in geographic study, as with other beginnings, must be painful drudgery. There is no fun in learning to read, to write, to spell, to do sums. Why should it be expected that in geography one will be exempted from the toil of the neophyte? Yet that seems always to have been the assumption with geography. The older elementary texts, while more insistent on names and locations, were undiscriminating as to the relative importance of the items to be inculcated; which was bad enough. But worse was the fact that in them it was sought to sugar-coat the locational pills with an ill-assorted miscellany of supposedly interesting and pertinent facts and statistics. The effect of these gratuitous insertions was chiefly to distract the student's attention from the task in hand, that of mastering locations and names. Realization of the defects of the filler material has led text-book writers of a later time to devote their energies to making the interlarded stuff rational, coherent and interest-compelling. In this ambition they have been quite successful. But the changes they have wrought have thrust the fundamental, locational geography so far into the background as to depose it almost completely from significance.

Beginnings in geography, as in other studies, are mnemonic. We can do 9 x 8 and 12 x 12 without setting down any figures on paper. But 13 x 17 stumps us because we never learned multiplication tables to include those figures. As with the multiplication tables, so also in geography, the locations, which are the 9 x 8 part, and the names, which are the result part, 72, should be learned by rote. There are of course limits beyond which it would not be profitable to go, just as there are limits with multiplication tables. In America the states of the United States should certainly be mastered, and perhaps as an extreme the counties of England—the counties of England because these have a historical and literary significance for an English-speaking people not possessed by the kingdoms of old Germany or the provinces of France.

In the beginnings of geography it should be as with, "c-a-t, cat," and "the cat is on the mat, m-a-t, mat," in reading and

spelling, and not, "the cat is kin of the lion and tiger and other beasts of prey." It is not meant that in geography there should be no devices to facilitate the mnemonic processes and to give the training significance. Only that the distractions, the attempts to rationalize, shall be ruled out in the first steps. Thus with third-year and fourth-year students there might be used the device of a suspended globe, as large as could be conveniently got at by children of the stature then attained. On this globe the outlines of continents and islands would appear and the latitudinal and longitudinal net. The surface of this globe would be perforated, further, with a multitudinous system of sockets, of varying size and marked perhaps with rims in different colors. Each socket would be the place for planting a flag bearing the name of a continent, a state, a river, a city. It is unnecessary here to elucidate further in regard to the mechanical details. But it will be appreciated that, however the initial drill in learning the locations and names is carried out, the student who, on test, being given an assorted lot of flags could without hesitation plant each one in its appropriate socket on such a globe would have a knowledge of locational geography very few of us possess.

After that the student could pursue with profit and interest, and without harm, the study of the average "First Book" of the elementary geography texts now in use. If, meanwhile, he could also, through "nature study," have been introduced to the phenomena of orientation, day and night, seasons, and to the reading of maps, his grounding for the study of the first book would be well rounded out. If, by observation of the North Star or the noon position of the sun from *different* points, the fact of parallelness of north-south lines could be established, for example, that would be enough. At this stage there would be no need to go into explanations. Similarly, the first steps in map reading could probably be taught best by using a simple map showing points that the student might reach by walking, but which were out of sight from the point of departure. The changes in direction of the route followed and the symbolism of the map would by this means be made self-interpretative.

The considerable digression from the main theme in which we have indulged has seemed necessary because the specific details presented make clear what a general statement only of the situation might have left obscure. Reverting now to the definition and the problem of geography, as set down in an earlier paragraph, it is of course evident that when locations have been learned we have only proceeded to the point of knowing what is to be described. An even more arduous task awaits, that of becoming acquainted with the

physical equipment of the earth. Much of this knowledge, too, must be gained by tedious exercise of the assimilative faculties, though a little salt of understanding may be used to season the diet. All this which relates to name, location and objective reality in the world is geography, however; no one disputes that, and it is expected of the professional geographer that he will gather these facts, classify and correlate them, and present them in appropriate form.

But when we enter upon consideration of the second clause of the definition of geography, as given, and which reads, "and of its inhabitants," we have to deal with a much more elusive and controversial topic. As with geology, and so forth, on the inorganic side, so also we find that botany, zoology and anthropology, on the organic side, are willing and able contributors to geography. On the other hand, history, economics and sociology have held themselves distinctly aloof; have shown no disposition to regard it as part of their duty to aid in the elucidation of geographic problems. More, they ask nothing, and will accept little, from geography.

That history, economics and sociology have set up a sort of "No Thoroughfare" sign against geography is one thing. Another is that geography has got itself all muddled up in attempting to include with her material the content of a branch of knowledge that as yet lacks a distinctive name. It might be called the science of agricultural practice, commercial procedure and of industrial processing, or, more concisely and generally, technology. Economics has adopted certain phases of the part termed "commercial procedure," and chemistry stands sponsor for some of the subject-matter of "industrial processing." But much of industrial processing and nearly all of agricultural practices have been saddled onto geography.

Here we digress again for a little to point out the second of the futilities in school geography. I open at random the most recently published of the geography texts, one which is used very generally in American elementary schools. I chance upon page forty and find that the whole of it is given to a description of a blast furnace and the smelting of iron ore. On pages 106 and 107 of the same book I learn how a sugar-cane plantation is conducted. On pages 142 and 143 of another popular text the procedure of a round-up of cattle on a western ranch is set forth quite exactly and the efficiency of modern meat-packing plants is exemplified by inclusion of a list, in detail, of the utilization of the by-products. The citations given are only samples. These and other books contain page after page of the same sort of material. But is such matter geography? Hardly. And if it were, why stop with telling how iron is smelted,

why not teach as well how to assemble an automobile or how to extract radium from its ores?

It may be desirable to teach elementary school pupils how corn is cultivated and how hardwood floors are waxed. But if these children are supposed to be studying geography they should be giving attention to matter germane to that subject and not to incidental accounts of how men deal with certain materials. It is owing to the inclusion of a multitude of such extraneous items, in what purport to be geographic texts and books, that geography is so generally considered a repository for miscellaneous odds and ends of information for which a place has not been found elsewhere. Incidentally, it may not be amiss to suggest to persons who are struggling with texts and courses entitled "Introduction to Science" that what they really have in mind is to put before students in organized form the sort of information that the geography-text authors endeavor to comprehend in their descriptions of a blast-furnace and a packing plant. Discriminatingly selected and systematically presented, such topics could be made the basis of a worth-while course, in the junior high school, say.

But this text-book aberration can be corrected. A more serious difficulty is presented in the non-cooperative, self-sufficing attitude in relation to geography evident in historic, economic and sociologic studies.

While the writings of historians, economists and sociologists, in general, do not directly express the exclusion sentiment herein imputed to those sciences, they do reflect it. It seems to be felt, in some degree, by workers in each of these fields that the world looks to them for an explanation of the present state of man. The historian apparently considers that when the nature and succession of institutions, the character and motives of personages and the march of events are adequately known and understood the present ordering of the world and of mankind will be sufficiently elucidated. Similarly, the economist would have us gather that the evolution and contemporary status of man's utilization of the earth's resources, and of his dealings with other men, are the key to the problem, and the sociologist would find its solution in the history and nature of man's gregarious activities. On the other hand there have been geographers who insisted on a "rigid determinism," that is, a control and direction of all human affairs past and present by geographic influences, the dominance of environment.

The list of phrases current in discussions of the import of the geographic factor on human affairs is already so long that it will do no great harm to add another to the number. This will be "determinism through adaptation." By determinism through

adaptation it is meant to express the fact that, whereas each geographic environment presents certain opportunities to mankind, the nature and degree of the utilization of these opportunities will depend on the kind of men who enter upon their exploitation. A given group of men will therefore be successful in the degree that its activities are permitted by and suited to the place. Some sort of adaptation or adjustment there must be or the group will not survive. So much there is of determinism. But it does not follow that the previous history and personal characteristics and habits of a people will have no bearing on the adaptation which develops. These factors will affect greatly the kind or nature of the adjustment that will be attempted. When agricultural settlers from the humid east of the United States first invaded the grasslands of the semi-arid border of the Great Plains they attempted to occupy the new areas under the system of farming and living which was successful in their old homes. But this system did not fit the new environment. Consequently, there had to be an adaptation involving many modifications of the old system. It was found, for example, that six hundred and forty acres, rather than one hundred and sixty acres, were needed for a homestead in the semi-arid country. Had these settlers come from other dry lands they might never have attempted the extensive utilization of the land which the immigrants from the East have now established, but would have, instead, confined their activities to narrow alluvial lands and limited tracts of irrigable acres. The environment fixes certain conditions; man adjusts himself to these conditions variously.

Grant that it is the business of geography to describe the earth and its inhabitants—chiefly man, then one may ask: In what spirit, from what viewpoint shall that description be presented? And the answer is: It should be an interpretative description. From geographic science we should expect to gain an understanding of man as he now is and wherever he is, in relation to his environment, inorganic and organic. Here the reader may exclaim "Huh, that is assigning to geography the most significant rôle among the social sciences." Precisely that. Geography should be the correlating and synthesizing science. Other branches of knowledge have two functions. They are concerned with the investigations of special fields, and in some degree they serve as handmaidens to geography.

It may not fairly be said that in this absurd pretensions are raised for geography. It is a position already tacitly granted to geography. If one is seeking information about Tasmania and Tasmanians of the present one does not turn to histories or economic or sociologic works. Rather one seeks a book or an article on the

geography of Tasmania. If it is desired to know the order and origins of the Tasmanian culture, then historical and sociological writings should be consulted; for the operation of governmental institutions and the industrial practice, works on political economy are indicated. The difficulty under which geography labors is not so much that it is denied the function of correlating and synthesizing science as that geography and geographers have failed to perform their duty. The sought-for, truly *geographic,* interpretative book or article on Tasmania and Tasmanians is probably not to be had.

Tried and found lacking would therefore seem to be a sufficient explanation of the low estate of geography. Why make a pother about the fact? Because only a few years ago American geographers in formal assembly were evidently agreed that regional geography of the indicated, interpretative type was the major problem of the science. Since then part of this group, at least, has been converted to a new point of view and method of approach to geographic problems, and that one which threatens to involve the science in a new series of mazes without giving promise of any adequate return. The true, interpretative geography is now said to be "human geography" and it has side issues, like "land utilization," which have an economic bearing.

And this, too, just at the moment when for the first time there seemed assured the active cooperation of the economists and perhaps of the historians and sociologists. An eminent economist recently came before a meeting of geographers and presented the case of economic science as in need of help, and the help wanted was from geography and geographers. The motto of the economist's appeal was: "Under all the land." And the geographers, who have long been protesting against being classed as pedlars of irrelevancies, instead of eagerly accepting the implied invitation to geography to give point to economics by answering, "We will pursue our regional studies with vigor so that you may have at your disposal the geographic facts which will permit you to apply economic science," replied rather: "Yes, yes, we will adopt economic methods; we, too, will study man's activities, we will come at a true understanding of geography by use of statistics and other befuddlements." They overlooked altogether that the motto of the economist's appeal was "Under all the land." A strong program for straightforward research in regional geography, which had met with approval some years earlier, had evidently been altogether cast aside. Instead these geographers seemed desirous of giving the impression that they were engaged in labors extremely recondite, requiring long-continued and arduous efforts to secure results.

If the issue here presented was one that concerned professional geographers merely there would be little excuse for bringing it to the attention of readers outside that circle. But the matter does have a broader significance. It is important that instruction in geography should be sound and to the point. It is also important that geographic research be directed to the securing and preparing of adequate and authoritative, interpretative, regional descriptions to the end that political, economic and social adjustments may be made on a sound basis. There exists a great demand for such studies. The public seeks geographic enlightenment. Travel books have a wide sale. A certain geographic magazine enjoys a tremendous vogue because it publishes each month a multitude of pictures showing lands and peoples far and near. These illustrations depict regional geography. The age of exploration has almost passed, but the average man is now engaged in making his own voyages of discovery. If geographers will not supply him with illuminative text the other fellow can at least make his own interpretations from the pictures so freely provided.

In order to understand why the pursuit of "human geography" is apt to lead to futilities, it is necessary to be clear as to how it differs from the interpretative, regional geography herein urged. Those who adopt human geography as their method of approach to geographic problems seek to find in human activities and in the results of human activities the clues to geographic understanding.

Thus, for example, it is pointed out that the arrangement and clustering of human habitations in one region is different from that of another; accordingly, the reason for this difference is to be sought out. By analogy, assume that a woman appears in a certain sort of dress. Then by looking at the dress it is expected that one should understand the woman. There is something of truth in the philosophy here followed, and it may be suspected that modern femininity has come to the same conclusion. Hence, perhaps, the shedding of raiment in order to be more securely inscrutable. In flapper guise the maid of eighteen may not be singled out from her of thirty summers. Nevertheless, it would probably be conceded that Eve stood more revealed in the Garden of Eden than when garbed in mid-Victorian propriety. Human geography seeks to understand the environment by noting what the response to it has been.

The influence and works of certain European geographers, especially of P. Vidal de la Blache and, more recently, of Jean Brunhes, are in large degree responsible for this trend. A quotation or two will serve more truly than much analysis to give acquaintance with the method and manner of these leaders. Thus Brunhes:

But if we cast a general glance over the earth, we soon see a whole new and very extensive series of surface phenomena; here it is cities, there it is railroads; here it is cultivated fields, there it is quarries; here it is irrigating canals, there it is salt marshes; and in all lands are more or less dense masses or groups of human beings. These human beings are, in themselves and by themselves, surface facts and therefore geographical facts. They live *on* the earth. They are subject to atmospheric and terrestrial conditions. They belong to certain climates, to certain altitudes, to certain zones. Besides they live *from* the earth; it is by subordinating themselves to natural phenomena that they assure to their bodies the necessary conditions for life and growth and to their faculties, development and expansion. . . .

The ensemble of all these facts in which human activity has a part forms a truly special group of surface phenomena—a complex group of facts infinitely variable and varied, always contained within the limits of physical geography, but having always the easily discernible characteristic of being related more or less directly to man. To the study of this specific group of geographical phenomena we give the name "human geography."

And this from P. Vidal de la Blache:

The *characteristic quality* of a country is thus a complex thing resulting from the delicate and varied interaction of many factors.

As Brunhes suggests, a certain "spirit of finesse," of mental suppleness, is essential to carrying on the type of studies he outlines.

The kind of geographic description which results from this attitude is exemplified by the following, again from Brunhes.

The village type is in itself a geographical fact, both in the way it expresses the nature of a whole region and in the way its appearance and position depend upon its immediate surroundings. The picture of the village of Salo ——————— : Slopes almost entirely green, of two greens combined, one bright, the other almost black, forming from afar one somber color; on this background, in no sharp contrast, are light or dark gray rocks. What does stand out upon these high and steep but harmonious slopes, what gives them life, what produces the opposition of shades and lines, is the white village against the dark background. Each village spreads horizontally along the hillside, breaking the main lines of the long slope, its dazzling points forming one level curved line, relieved and dominated by the vertical shaft of the bell tower. And as if to complete the harmony and to reproduce in exact miniature the deep, dark color scheme of the whole, each long white village is broken by dots of shadow formed by the arcades, and the whiteness of each house is broken by the dark window openings.

Word pictures such as this may have a place in the ultimate content of geographic literature.[2] But it is work which may be likened to that of gleaners in a harvest field, or of decorators in a nearly finished house. It is interesting to note that even Brunhes confesses that it is "difficult to make out what is really and strictly geographical in the manifestations of human life in vast dissimilar

[2] The chapter by an American geographer in the English translation of Brunhes's book, "Human Geography," is a very nice piece of regional geography even though it was intended to be a sample of human geography.

settings," "wholes as complex as France or the United States." Hence, he suggests, simple units, five types of little, geographical worlds, seem especially marked out for the observations of the human geographer. These are islands: the islands of the sea; the islands of the desert, oases; islands of population in arctic wastes and equatorial forests; the island of the closed mountain valley, and the island of isolated mountain areas surrounded by plains. And while Brunhes may be warranted in thinking of the area he proposes to study as such an island it is nevertheless regrettable that the "spirit of finesse" displayed in Brunhes's studies should inspire a young American geographer to declare publicly "that although he had been in Patagonia and other far places he was done with geographic studies of extensive and remote areas until he had mastered in detail Chicago and its environs for thirty miles round." What a terrible ambition. What depraved geographic taste to desire to be engaged indefinitely in grubbing about *Chicago!*

Human geography will make its followers unable to see the forest because of the trees. Another young American geographer is already involved in what may be considered one of the outgrowths of human geography, namely, "land utilization." He expresses the objective of land utilization studies to be (in part) as follows:

> In the study of present utilization the condition of the land is under scrutiny, as to kind of use, productive returns of each type of use, and the effectiveness of kind of production as related to type of land. In this manner the area may be broken up into smaller parts, each characterized by a distinctive system of production, and usually differing in returns as well. In so far as this type of study can be expressed by a map, the map will reproduce the landscape as a mosaic of differing economic practices, usually, though not necessarily, closely related to different types of land.

The idea seems to be to mate economics and geography for the production of a mongrel which shall have something of the qualities of both parents. That the mongrel should exist is bad enough; that geography is expected to play mother to the cur is even more objectionable.

Perhaps that is condemning a worthy project without fair trial. However, the same young geographer who proposes this research in land utilization also penned these lines comprising part of a study of the regional geography of the Ozark Highlands:

> The main roads follow ridge tops. Their location is determined by low cost, freedom from floods and freedom from erosion. They are passable throughout the year, but serve directly only the settlements on the ridges. Over large sections these settlements are not flourishing, nor as promising for future developments as the valley settlements. It is notorious that the traveler on the main roads sees very little of the better land. The ridge roads are separated from the valley farms by steep hills. Connection between the two is made by

rough and often badly washed side roads. The secondary roads that follow the valleys are subject to flooding with every freshet and are often washed out. Fords are innumerable, bridges few. The location of roads was determined by the easiest lines of travel. . . .

Here one begins with the first sentence to get an understanding of the Ozark country in its broader geographic aspects. And despite the largeness of the drawing it is an intimate picture. Why struggle with the statistical details of census figures, tax assessments and crop returns and bring forth a mouse, while we still lack, for the larger part of North America, the effective delineations of regional geography such as this man has provided for the Ozark area?

In part human geography is a reaction to the rigid determinism and the unsupported, or rhetorical, generalizations with regard to geographic controls and influences which preceded it. Human geography proposes to be inductive (with occasional lapses) whereas the earlier studies were deductive. It is not to be denied that the anthropogeographers, of whom Ratzel was the leader, struck by the potency of certain obvious geographic relations in shaping the course of history, were encouraged to range far afield and indulge themselves, and the world, with such fancies as that the love and cultivation of beauty by the ancient Greeks was a direct response to the variety and interest of the Grecian landscape.

Like the modern "human geography" these speculations originated in Europe. Meanwhile, however, there was developing in America, initiated by the studies of Dutton, Powell and Gilbert, and carried forward to a rounded whole by the master work of Professor W. M. Davis, of Harvard, the science of physiography or the explanatory description of land forms. Davis showed that land forms, like life forms, go through an evolutionary cycle, have a life history. Mountain, stream valley and shore line have each their successive steps of development, and in the same stages have comparable characteristics. It becomes possible to analyze landscapes of the most complicated type, to trace out their past and to predict their future forms. Moreover, once a landscape was identified by characteristic earmarks to belong in a certain category and stage, it also followed that it must exhibit certain other qualities and conditions that go with the form in question. Henceforth, to name a particular physiographic form was to describe the landscape as well. Relief forms from all over the world could be compared with exactness and their relation to human activities appreciated, even though the train of consequences did not everywhere appear to be exactly the same.

From this systematic knowledge of relief forms there grew up

the concept of physiographic provinces. Further, there has developed a general accord among American geographers as to the delineation of the physiographic provinces of North America, and more particularly, those of the United States. During the period in which this sorting out of the provinces was being done it was thought that, once satisfactorily outlined, such areas would provide the fundamental units on which regional geographic descriptions could be based. But it was found that they would not so serve, that something more was needed. To express this requirement of a regional, geographic unit dependent on the physiographic province, and yet distinctive from it, the term "natural region" was suggested.

The natural regions of North America have not yet been outlined satisfactorily. It is recognized that, second to physiographic expression, and perhaps of equal importance to it, the geographic factor of climate must be considered in fixing upon natural regions. The distribution of mineral resources and of avenues of overland routes of transportation must also be taken into account.

In the case of climate the accumulation of meteorological data has now progressed to the point where it is sufficiently comprehensive to permit its use in researches of a synthetic kind. A number of geographic students are at present engaged in this task of developing climatic characterizations. It is a work that promises much. As their various efforts are in turn correlated we begin to see that certain combinations of the weather elements give rise to distinctive climatic types. With reference to the human occupation of the earth each of these climatic types will have a definite and convincing relation. And when the climatic type is fitted to the physiographic province we can expect to see an emergence of natural regions in their larger units. On the other hand, certain areas indicate themselves so clearly as natural regions through the concurrence and systematic correlation of all the geographic items they exhibit that they do not need to await analysis for their delineation. They almost mark themselves out on the map. Consequently, another group of American geographers is engaged in the task of fixing upon these recognizable natural areas, with the expectation that their characteristics will furnish clues for further divisions of the land into areas of geographical unity.

In these several endeavors true and orderly progress may be discerned. Surely it is well to have knowledge of the gross anatomy of the body before attempting histological studies. Here we revert again for a moment to the land utilization project. One young promoter in this field has been quoted. Another energetic worker with similar ideas has recently published a paper dealing with the dis-

tribution and possible densities of population in relation to the ultimate food supply. His analysis is clear and his classifications are good. But he too urges that the immediate task of the geographer is the undertaking of an infinitely detailed survey of the land surface of the world. He is more rational in that he proposes that this survey should proceed from the large to the small, from world regions to physiographic provinces, narrowly subdivided, to natural districts which, with him, are very narrow areas in regions which already have a considerable density of population. With this scheme of procedure no fault need be found. It is, however, the end result, the exact knowledge and delineation of the small natural district, in which he is primarily interested. A significant difficulty, then, with his proposal is that what he wants done is something which will be indefinitely deferred. Recognizing this difficulty the other group of land utilizers have in view solving the dilemma by making their attack through study of the human geography of the small area.

Wide regions of the earth's surface have not been accurately mapped as yet; the topographical mapping of the United States under governmental auspices, and supported by large annual appropriations, will require at best twenty years more for its completion. Hence the very base for the detail studies is lacking. Again the prodigious effort in research necessary to carry through such a project in any reasonable time would require a force of geographers vastly greater than the available supply, all to be provided with a livelihood while engaged in the work. As it is, geographic studies are almost all desultory, engaged in by individuals as their enthusiasm or interest may dictate, with some aid from public and private sources. That will no doubt continue to be the situation. Systematic and comprehensive histological geography—yes, perhaps two hundred years hence.

Aside from the physical difficulty, there is another even more vital defect in the "land utilization—ultimate population density" proposal. Unostentatiously slipping into and out from the discussion is the suggestion that the findings of the survey should be related to a maintenance of the present standard of living. Evidently even vaster numbers of people, than at present, are in the future to be doomed to poverty and misery. Surely not an optimistic outlook. And if the standard is to be raised, to what degree? Here certainly we leave the domain of the geographer and enter the realm of the sociologist and of the economist.

In passing, one virtue of the human-geography method should, however, be noted. In making the approach from the human-activity side many observable items of the human occupation of the

earth will be immediately and clearly found not dependent on, or related to, the physical environment. They may be dictated by circumstances, historic determinations or by perversities of human nature, matters of sociological development. Whether or not these should be considered as instances of minor maladjustment to the geographical situation will depend on the point of view. In any event, thus brought to light, they can be eliminated from the geographical problem, which will then by so much be cleared up.

Reliable and sufficiently comprehensive census figures and statistics of production for the world have been available only within recent years. As these came to hand with satisfying completeness a science developed for showing graphically the facts of distribution contained in the figures The map pictures to which this gave rise were fascinating studies, they made safe deductions possible where before there could be speculation only. Also they directed attention very emphatically to man's being and activity on the earth and the results of such activity. In part, then, human geography got its impetus legitimately enough from the accumulation of census figures and the demand that these be analyzed geographically.

A word more, finally, with regard to the program for geographic instruction. When the facts of locational geography have been patiently learned by rote, when through simple observational study the young pupil has been made conversant with the elements of orientation and of map reading, and after he has been introduced to the position of the noon sun as the clue to day and night, seasons and longitude, then he will be ready for a systematic study of the regions of the world. It is not essential that the text used for this purpose should be built up, in monotonous succession, of topics headed, location, size, physical features, climate, soil, chief products, cities, etc., for each region studied, as was once the case. Instead, it should be quite possible to develop the study of each region as related to some central theme, which will give expression to the dominating geographic factor in that area. The treatment may even be keyed to an "emotional" pitch as one critic of elementary geography suggests it should be. Certainly it should be inspirational. But the demand for interest, through variety and liveliness in the manner of presentation, is not, however, to be construed as giving excuse for including accounts of how blast furnaces are operated, corn cultivated or how cattle are branded. The rule should be to include as much as is practical of geographic significance and to discard altogether the non-geographic items.

As, under the prevailing system, geographic instruction terminates in the grades, and in some cases is not carried beyond the sixth grade, the "spiral" treatment now in vogue is altogether wrong. By this method the pupil in the sixth grade or in the sixth

and seventh grade goes over the same ground in a second book that he has covered in the lower grades. The only differences are that the content of the second book is greater, and that the material is not organized in the same way as in the first book. Furthermore, the individual who completes a high school course of study probably does not get in the majority of cases any additional instruction in geography.

If the unessential matter were omitted in both books much of the fuller statement of the second book could be included in the first book. Then the way would be cleared for an intensive study of one continent, North America, in, say, the seventh grade. While the purpose of education, ideally, is to prepare the individual for living rather than for earning, it avails nothing, in furtherance of this ideal, to be blind to the fact that the student whose formal education in geography will stop with completion of the seventh grade is in greater need of vocational than cultural training. In the majority of instances, moreover, it is probable that the life interests of such students will be focussed on a very narrow region about their home areas. If he will never be able to see that far in after life the student will have but little cultural gain through being provided with a world horizon in the elementary schools. On the other hand he will derive great cultural, as well as material, benefit through having a detailed knowledge of the geography of his home region, his home country and his home continent, North America.

If circumstances permit continuance of study beyond the elementary grades geographic instruction through the high school years might include elementary physical geography, elementary technology (perhaps under the guise of commercial geography or industrial geography or introduction to science), elementary meteorology and climatology and elementary astronomy. Then the student would be ready, during a college career, to pursue studies in systematic, regional geography concurrently with studies in history, economics and sociology.

No doubt there will always be those who will insist that the greatest human successes are achieved by the individuals or groups that best understand mankind and men's motives and activities; hence that history and human geography are indicated as the studies especially to be emphasized for the promotion of successful living. But to this it may be replied that if all men knew all the earth, its regional possibilities and limitations, and would adjust themselves to these natural conditions and cooperate in the development of the world environment, much that distresses in man's behavior and which one would learn to circumvent through knowledge of human geography, history, economic and social science, would tend to disappear.

THE PROBLEM OF AN AUXILIARY INTERNATIONAL LANGUAGE AND ITS SOLUTION

By Dr. MAX TALMEY
NEW YORK, N. Y.

In its report on the scientific value of an artificial language published in 1887 the American Philosophical Society points out the harm done to science by the application of many languages as follows:

> All nationalities have the honor of publishing their scientific productions in their own languages so that there are now scientific works not only in all the principal European languages, but also in Rumanian, Czech, Magyar, Armenian, Japanese. The confusion of languages in scientific publications has grown to such an extent that the great scientist Max Müller has been induced to appeal—but in vain—to his confrères to restrict themselves to the six languages, English, French, German, Italian, Latin, Spanish. This, however, would be a very insufficient remedy. For where is the student who could learn only to read those six languages?

The preceding remark is clearly illustrated by the experience of Professor William Marshall in his study of the epoch-making theory of my early friend, Professor Albert Einstein. Professor Marshall summarizes the difficulties of studying the theory in the following words:[1]

> All the work about the theory is scattered through research journals in some six languages so that it is not very accessible. Fifty or more articles include those in three languages, only those which an ordinary mathematician and physicist could read without too great an expenditure of time and energy.

No better illustration of the detrimental effect upon scientific investigation caused by the multiplicity of language could be given than this embarrassment of Professor Marshall in his study of a new theory which bids fair to revolutionize physical science.

Another illustration is furnished by Professor Einstein himself when he lectures in foreign countries. During his visit to America in 1921 many American mathematicians, physicists, philosophers, etc., came from all parts of the country to hear the most ingenious physicist himself expound his theory. But, with the exception of the German-Americans of the first generation, very few of the listeners were able to follow the speaker properly. He had for his lectures no language that he and his hearers might have understood

[1] *Popular Science Monthly*, May, 1914.

equally well. He did not want to speak in a language in which, at best, he would have been far inferior to them. Free lectures in an unfamiliar tongue would have imposed upon him a great burden without enabling him to express his thoughts with as much clearness and precision as in his mother tongue. Any foible shown would have given his listeners cause to look down upon him benevolently. He, therefore, chose his mother tongue for his lectures to the great disadvantage of the American students and scientists. Scholars in other countries have the same experience since Professor Einstein never uses any but his mother tongue in public lectures.

Merchants engaged in international commerce suffer even more than scientists from the want of an auxiliary international language. Besides increased expenditure of time and energy they have to bear increased expenses for interpreters and for special clerks needed in their foreign correspondence. Similar difficulties are encountered by those traveling through foreign countries for professional and other reasons.

The importance of an auxiliary international language for diplomacy has been evidenced not very long ago at the Russo-Japanese peace conference at Portsmouth. The beginning of the negotiations was retarded for several days because the plenipotentiaries did not understand a common language and interpreters could not be had quick enough, a fact that was then prominently discussed in the daily papers. Meanwhile the whole world was waiting with great concern for the final act which was to conclude an international tragedy. Also, at the termination of the latest and greatest world tragedy at Versailles an undue delay of the negotiations took place. Perhaps it was caused partly by the inability of the American delegates to converse in the French language. At any rate they certainly were not able to argue the American cause by means of the French language as well as the Frenchmen could argue theirs.

The unequal position of the various participants in an international affair can be observed in all international gatherings. The tendency towards international institutions has been growing more and more owing to the great progress of science and to the immense improvement of the means of transportation. There are international societies for the promotion of science, technique, commerce, world peace, morality and wireless intercommunication. Especially to be mentioned is the International Association of the Academies. These societies convene congresses and at such occasions the want of an auxiliary international language renders intercourse between the participants very difficult and causes great inconveniences to

most of them. The position of the majority of the participants is disadvantageous, while that of a few others whose language is used at the gatherings is very favorable. In this respect the eminent linguist Hugo Schuchardt makes the following pertinent remark in a report on the international language question submitted to the Vienna Academy of Sciences in 1904:

> The diversity of language hinders international communication in numerous instances, and where it can take place, either in writing or in speaking, it is only exceptionally effected in an entirely satisfactory manner, *i.e.*, so that the two parties would understand each other as well as two compatriots do and that one of them would not be overburdened.

The preceding considerations show clearly the desirability and the ever-growing need of an auxiliary international language. The nations will never concur in selecting one of the living languages for that purpose. For they will not consent to one nation gaining immense advantages thereby, especially in commerce. Besides, a living language is much too hard to acquire. The dead languages, too, are excluded because of the great difficulty to learn them and because of their slight adaptedness to modern conditions. Nothing remains, therefore, except to construct an international language artificially. In the report mentioned Hugo Schuchardt expresses these ideas in the following clear way:

> The adoption of a living language, not to speak of the imperfections inherent in all our languages, would engender an intolerable inequality between the nation whose language would be selected and all the other nations and would threaten the latter with utter denationalization. On the other hand, none of the dead languages can be recommended because of the difficulty to learn them. The only alternative is the adoption of an artificial language.

The objections against an artificial language are refuted by the great scholar as follows:

> The chief objection raised against an artificial language is that a language is an organism comparable to the human body, an artificial language therefore impossible like the homunculus. Language, however, is no organism, but rather a function, a social activity.

The learned professor continues here with a beautiful simile:

> An ancient city irregularly built or half in ruins furnishes the best motives to the painter and the most vivid inspirations to the poet. Will they prevent the historian from reconstructing, cold-bloodedly, the past of that city? And will all three object to the architect building a new city in conformity with the exigencies of traffic and hygiene? If the homunculus objection opposes the natural to the artificial, this is of no importance in practice. Do we not often replace, with the greatest success, natural productions and actions with artificial ones? Besides, the opposition of the natural to the artificial does not exist at all in the domain of language. The artificial languages are more or less

natural and the natural ones are more or less artificial. The artificial in our languages is especially extensive in the written languages. We can not place, therefore, an artificial language in radical opposition to a natural one. The tissue is the same in both, only the thread differs. Here it is finer, more entangled, there it is coarser, more simple. The sentimental and intellectual values of a natural language are real, but they do not lie in the language, but in our relations to it, not in the instrument, but in the manner we are accustomed to make use of it. Like Antaeus in contact with the earth so also can every one display his whole force only in his mother tongue. In comparison with it all other languages, natural as well as artificial ones, are cast into the shadow. It is true, with a foreign language one assimilates an essential part of the culture herein embodied. But that anybody could express his thoughts on the highest questions in two or three foreign languages with as much clearness and ingenuity, as much surety and ease as in his mother tongue, such a thing has never yet been observed. Be this as it may, experience has taught that whatever can be said in a natural intermediary language can just as well and even better be expressed in an artificial language.

These views agree completely with the judgment of another great linguist, Max Müller, who states that an artificial language is not only possible, but could even be more perfect, more regular, and more easy to learn than any natural language.

Some knowledge of the history of the attempts to create a universal language is indispensable for the proper appreciation of the problem of an auxiliary international language. Before presenting this historical review it must be expressly stated that no language inventor worthy of mention has pursued the aim of curtailing in any way the natural languages, least of all to replace them entirely by his project. This is especially to be emphasized because the erroneous impression prevails with the public that the advocates of an international language wish to abolish the natural languages. A similar notion may have been harbored by some visionaries, but has been far from the thoughts of all experts on the problem and of all language inventors. They merely strove to create an auxiliary language for all occasions of an international character. Some philosophers, it is true, were convinced that it was possible to construct artificially a language more perfect than any of the natural languages, but they did not want to retrench the latter on that account. This more perfect language was sought by them merely as an auxiliary language.

A universal language is first mentioned in the Bible:[2] "And the whole earth was of one language and one speech." In the same chapter the origin of the diversity of language is explained thus: "Go to, let us go down and confound their language that they may not understand one another's speech." In the prophet Zephania occurs this passage (III, 9): "For then I will turn to the nations

[2] Genesis XI, 1.

a pure language that they may call upon the name of the Lord to serve him with one consent." Some believe that in these words is expressed the desire for a common language for all nations. But this view is open to doubt.

As far as can be ascertained the idea of a universal language does not come up distinctly before the end of the 16th century. At that period new pathfinders arose in philosophy, introducing a new philosophical era. Some of those geniuses deemed the natural languages cumbersome and inadequate for the expression of logical reasoning because of their insufficiencies, ambiguities and illogicalities. The construction of a commensurate, logical and easy language for philosophy appeared to them expedient and feasible.

Theoretical views on a universal language are found in the works of Francis Bacon. The father of modern philosophy, Descartes, went further. In a letter dated Nov. 20, 1629, to P. Marsenne, he outlined a plan for a universal language. He postulated for it complete regularity and the possibility of understanding the language by the mere medium of a dictionary. The great mathematician and philosopher Leibnitz entertained the idea of a universal language throughout his career. He put up definite requirements for its grammar and vocabulary and offered a complete project. He never wrote a special work on a universal language, but numerous texts relating to his project are scattered throughout writings of his which are still inedited to a large extent.

Complete artificial systems of language had not been published before the first half of the 17th century. New devices appeared from time to time until our very days. About 250 systems have been constructed during this 300 years' period. In 1903, the French philosopher and mathematician, Dr. Louis Couturat, the able investigator of Leibnitz and the greatest authority on our problem, in conjunction with Dr. L. Leau, published an extensive volume on the history of the universal language, "Histoire de la Langue Universelle" The authors of this excellent work very appropriately divide the systems devised until then into three classes:

(1) Systems a priori. They disregard completely the natural languages and create their elements, *i.e.*, words and affixes, entirely anew and arbitrarily.

(2) Mixed Systems. They obtain their elements by borrowing some from the natural languages and by building others anew and arbitrarily.

(3) Systems a posteriori. They derive almost all their elements from the natural languages.

The systems a priori are the earliest ones, but some of them have

appeared even later than the more developed mixed devices and the most advanced systems a posteriori.

Systems a priori

The first a priori systems were the so-called pasigraphies, *i.e.*, languages fit only for writing. Early pasigraphies are those of Bishop John Wilkins (1641) and of the Marquis of Worcester. Two later pasigraphies have obtained practical application and official recognition, the International Code of Maritime Signs adopted in 1864 and the Bibliographical Decimal Classification proposed in 1873 by Melvil Dewey, president of the Association of American Librarians.

To the pasigraphies may be counted the mimic language set forth as universal language by some authors, notably Jean Rambosson in 1853.

Also the first devices intended for speech were a priori systems. Noteworthy is the so-called musical language or Solresol devised by the Frenchman Jean François Sydré in 1817. It is built out of the seven monosyllabic names of the gamut tones. Men like Victor Hugo, Lamartine, Alexander v. Humboldt were great admirers of the system. It gained many adherents in France and England.

The principal fault of the a priori systems is great difficulty. On one hand their elements are entirely new, on the other hand the devices have mostly a philosophic basis, being founded upon a logical classification of the ideas, upon a complete analysis of all knowledge. Besides, such a classification is bound up with the progress of science. A language depending upon this progress would often have to undergo radical changes Owing to these two faults the a priori systems have not acquired general recognition.

Mixed Systems

The mixed systems, however, had a remarkable success. They comprise Volapük and its derivatives. Twenty years before its appearance the famous philologist, Jacob von Grimm, had published a project for a universal language which belongs in the same class because it contains features a priori, although on the whole it is constructed a posteriori. Excellent conditions for a universal language are prescribed in this project:

(1) The universal language must be rigorously logical, *i.e.*, every word must have an unequivocal meaning and the formation of words by derivation and composition must be accomplished in conformity with fixed rules. The author adds this pertinent remark, "If the universal language did nothing else but remedy the

confusion of ideas produced in all our languages by the vague meaning of so many words, the trouble would be amply repaid."

(2) The universal language must be of unlimited richness.

(3) The universal language must have a harmonious sound like Italian, Hungarian or Turkish.

(4) The universal language must be extremely easy to learn, to write and to speak.

This excellent project is greatly impaired through an a priori feature which entirely nullifies the fourth requirement.

The main representative of the mixed systems is Volapük. It was invented by the German priest, Johann Martin Schleier, of Constanz Baden, and published in 1880. It spread rapidly in all civilized countries. In 1889 the number of those practicing Volapük was estimated at one million. A great many books and periodicals in and about Volapük were published. In 1889 the third congress of Volapükists took place in Paris and was attended by numerous delegates from all parts of the globe who spoke Volapük exclusively. Its triumph seemed to be final. But in the same year began its decline, which was more rapid than its ascent. Shortcomings of the language were discussed at the congress, but no agreement about the necessary reforms could be achieved. This became fatal to Volapük. From 1889 the propaganda for the language became slack and soon it ceased almost entirely. In 1893 the Academy for Volapük made a clean sweep of the language by devising an entirely different one, called Idiom Neutral. Volapük soon passed into history.

Volapük has two radical faults: The vocabulary is not international and the grammar is too synthetic in contrast with the modern languages which more and more tend to analytic construction. National words are frequently corrupted beyond recognition. No English-speaking person could recognize the expression "world speech" in the word "Volapük." These two chief faults and others, as inconsistency in the derivation of words and the application of idiotisms, particularly German ones, render the language very difficult. Besides, it lacks euphony, containing various sounds that are hard to pronounce.

Volapük has the inestimable merit of having furnished for the first time the experimental proof on a large scale that an artificial language for writing and speaking is possible.

Other mixed systems, as the Blue Language (Léon Bollack, 1899), etc., have had no practical application.

Systems a Posteriori

The construction of artificial languages is much further developed in the a posteriori systems. Worthy to be mentioned are Nov

Latin[3] and Idiom Neutral.[4] The American Philosophical Society, in 1888, published a plan for an international language which has been realized in the best a posteriori systems.

Of these only one has obtained general recognition and practical application, Esperanto. The latter represents the second successful experiment, on a large scale, of the possibility of an artificial language and comes near Volapük in regard to practical success. It was published in 1887 by the Russian physician Dr. L. L. Zamenhof, of Warsaw. Until 1896 it had not acquired any noticeable propagation. In that year the Frenchman, Marquis L. de Beaufront, began to take interest in Esperanto. He published textbooks, dictionaries and a large Esperanto magazine. Thereupon the language spread rapidly in France and all other countries. In 1903 the number of those practicing Esperanto was estimated at 50,000 in all countries. This number increased in the next three years to a very great extent. In the United States Esperanto was almost unknown until 1905 In this year the writer became acquainted with Esperanto and after long search he succeeded in finding in New York City half a dozen people who knew something about the language. With their help he founded the New York Esperanto Society. Soon afterwards he published the first complete English text-book of Esperanto. These two events were reported prominently in magazines and daily papers. This directed the attention of the public to Esperanto, and soon Esperanto clubs were formed in several large cities of the United States.

But great practical success of an artificial language may be only transitory, as we have seen with Volapük. Indeed, its history is repeating itself in Esperanto, only at a slower pace. Competent students of the problem saw the substantial defects of Esperanto right from the start and pointed them out. Yet they advocated it because of its good features and because its faults seemed to be capable of correction.

The opportunity for introducing the necessary reforms came in the fall of 1907. At that time the International Delegation for the Adoption of an Auxiliary International Language, founded by the International Association of Academies in 1900, convened in Paris for the purpose of fulfilling its mission. A committee of the delegation composed of scholars of international reputation examined many artificial languages and found them all unfit for the rôle of an international language, including Esperanto. The committee recommended a system presented to it for examination by an author

[3] Dr. D. Rosa, 1890.

[4] Volapük Academy, M. Woldemar Rosenberger, 1902.

under the pseudonym Ido whose identity was then unknown. The wording of the committee's decision to this effect was composed in a form favorable to Esperanto in order to win over the great number of those putting implicit confidence in Esperanto. The decision reads, "The Committee has decided to adopt Esperanto in principle under reserve of certain modifications to be executed in the sense of the project of Ido." Any other a posteriori system modified in that sense would have given the same result; for these systems resemble each other a great deal. It is entirely erroneous to call the new language simplified Esperanto. One might, with more justice, call it simplified Idiom Neutral, Nov Latin, etc. The vocabulary is the chief part of a language, and in this respect the new language of the delegation stands much nearer to the devices just mentioned than to Esperanto, which violates the a posteriori principle extensively. Grammatically, the new language has in common with Esperanto nothing but seven of the so-called grammatical endings and a few suffixes. The idea of using grammatical endings is not even original with Esperanto, but already contained in much earlier systems,[5] and even the same grammatical endings as those of Esperanto are found in these systems.

The committee of the delegation recommended an understanding with the International Esperanto Committee of which the writer was also a member. A permanent commission for the perfection of the project of Ido was formed, and the committee of the delegation adjourned.

The permanent commission had no success in trying to bring about the understanding with the Esperanto Committee. The pretended majority of the latter positively refused to recognize the necessity of reforming Esperanto. From now on the dogma, demanded already previously by influential Esperantists, that the language is inviolable and not subject to criticism became firmly established. The degeneration of Esperanto through its intrinsic faults continued now without restraint since the most capable adherents gave it up, turning their attention to the project of Ido.

A comparative estimate of Esperanto and Ido will be more clearly understood by an exposition of the requirements and principles indispensable for a logical international language (IL). The vocabulary of the latter must be based upon the principle of the maximum of internationality and the a posteriori principle: the words of the IL must be as much as possible international, *i.e.*, common to the principal living languages; a conception for which no international word exists is not to be expressed by a word arbi-

[5] "Langue universelle," by Faguet, 1765; "Pantos-Dimou Glossa," by Rudelle, 1858; "Weltsprache," by Eichhorn, 1887.

trarily invented, but by one taken from some natural language living or dead (national words). The vocabulary of the IL will therefore consist partly of international, partly of national words. The objection that this lack of uniformity would impair the IL is refuted by the most efficient and most expressive language, English, which is composite to a very great extent.

The principle of internationality does not apply to the races who have been backward in civilization for thousands of years. Their idioms are undeveloped and foreign to the languages of the races who have been the bearers of civilization. A combination of the two would be a repugnant mixture, like Pidgin-English.

Those who speak of Chinese as the IL to be selected, at least partly, do not consider that the 400 millions of the celestial empire do not speak one language. Even the words of the dialect most diffused in China are unfit for the IL because they are pronounced with a certain musical tone which is as important for the meaning of a word as its consonants and vowels. If the words were adopted without their tonal character, they would be unrecognizable to the natives and the IL would abound in ambiguities.

The words of the IL must be phonetic, *i.e*, every letter or letter combination is to be pronounced always in the same way.

Euphony, too, is an important requirement of the IL. Its sound must be pleasing. This excludes letters or letter combinations hard to pronounce.

The preceding two requirements necessitate slight changes of a posteriori words, for instance, the replacement of the sign ph by the sign f, or of the sign c by the sign k whenever the former has the sound k; or the omission of s or x before c, as in the roots scienc, excit, which have to be changed into cienc, ecit. Actual mutilations of a posteriori words, however, must never take place. There is no justification for deforming the English word "speak" into "pük" (Volapük), or the roots "cerebral," "frontal," etc., into "cerb," "frunt," etc. (Esperanto).

The words discussed so far are original or root words. Other words are obtained from these by derivation. One of the cornerstones of a logical language is regularity of derivation. The latter is intimately bound up with the grammatical constitution of a language. A preliminary short description of the elementary grammar of the IL is therefore requisite for an exposition of derivation. The grammar of the IL must be of utmost simplicity, reduced to a minimum. If possible, a given text should be intelligible at the first glance as far as grammar is concerned. There is only one means to accomplish this; it consists in making the main parts of speech recognizable by invariable characteristic endings. For the

verb (infinitive), substantive, adjective and adverb these endings are respectively -ar, -o, -a, and -e. These endings are called grammatical endings because they show at once the grammatical rôle of every word in a sentence. They have no meanings by themselves, which is a very important point in derivation.

We can now take up derivation. One word is transformed into another one, for instance, a verb into a substantive, by changing the grammatical ending. This transformation is called the immediate derivation because no new element of idea has intervened between the derivative and the original, both expressing essentially the same idea under a different grammatical rôle. The derivative does not contain an idea not contained in the original.

Sometimes an additional idea, *i.e.*, one not contained in the original, is to be imparted to the derivative. This form of derivation can evidently be accomplished only through affixes which have meanings by themselves. This mode of building new words from given ones is called mediate derivation, because the derivative is obtained from the original by the intervening of an additional idea indicated by an additional formal element in the derivative.

The meanings of all derivatives are determined by several principles. The fundamental principle for a logical language is the principle of unambiguity propounded by Professor Wilhelm Ostwald: every element of a word, as root and affix, must have but one invariable sense which it must retain in all combinations it may enter into—one sign . . . one invariable sense. The writer has amplified this principle as follows:[6] Every formal element of a word must be represented by an element of idea in the meaning of the word; further, no formal element of a word consisting of several elements may lose its meaning. It follows that the meaning of a word composed of several elements must contain the meanings of all of them, but no other idea.

The meaning of a mediate derivative can now be determined very easily. It is composite, it consists of the meaning of the original and that of the affix.

As to the immediate derivatives it is to be borne in mind that, as a rule, the sense of a word is contained in its root alone.[7] A root is transformed into a word by adding a grammatical ending. The primary word formed from a root is the one corresponding to the sense of the root. Thus the primary word derived from the root mov is the verb mov-ar = to move; from the root pal the adjective pal-a = pale. Secondary words are formed from primary ones by changing the grammatical endings of the latter.

[6] Filologiala Temi, p. 14.

[7] Fil. Tem., pp. 12, 49, 58.

The meanings of secondary words are determined by the inherent relations between the various parts of speech.[8] One such relation may be explained here. The relation between the verb and the substantive derived from it immediately is that the latter signifies: act expressed by the verb; for instance, divid-ar = to divide; divid-o = division, act of dividing.

The correctness of a derivation can be tested by what may be called "the principle of the additional idea": every additional idea (idea not contained in the original) in the meaning of a derived word requires an additional formal element in the word. For instance, natur-o = nature; suffix -al = relating to; natural-a = relating to nature, natural. This derivation is correct: the derivative contains the additional idea "relating to," which is represented by an additional formal element, the suffix -al. But it is wrong to derive a verb arm-ar with the meaning "to provide with a weapon, arm", "to arm", (from the noun arm-o = weapon, arm), for the idea "to provide with" is not contained in the original and there is no formal element in the derivative to express this additional idea.

Another adequate test is furnished by the following principle:[9] Logical derivation requires that a word of the original meaning be obtained in passing back from the derived form to the original one. This follows from the principle of unambiguity. For a derivative is obtained by changing the form of an original. When the latter is restored, the original meaning must be restored, too, since the same form must always have the same sense. The following example will elucidate this. It is wrong to derive a verb sal-ar with the meaning "to provide with salt", "to salt", from the noun sal-o = salt. For if we go back from the verb sal-ar = to salt, to the noun sal-o, the latter must now signify: act of salting (see above). The same form sal-o would thus mean once: the salt, another time: the act of salting. This violates the principle of unambiguity. The derivation is wrong because the original sense is not obtained in passing back from the derived form to the original one.

The meanings of composed words are determined by several principles as the writer has shown in a special essay on composition.[10]

We are now better prepared for a review of Esperanto. This system fulfils none of the above requirements and principles.

[8] See "Logical shape of the AIL," American Medicine, August, 1923.

[9] The writer's modification of Couturat's principle of reversibility, "Étude sur la Dérivation," p. 7.

[10] Filol. Tem., Nro. 1.

(I) Infringement of the principle of internationality and of the a posteriori principle is so extensive in Esperanto's vocabulary that it would be more justified to range this device among the mixed systems than among the a posteriori ones. Of the 2629 root words of the vocabulary 1055 violate more or less the principle of internationality[11] and the most frequently occurring words are entirely arbitrary so that Esperanto texts are unintelligible without a dictionary even to expert linguists who understand real a posteriori systems almost at first sight.

(II) Esperanto has no regular system of derivation and therefore it abounds in irregularities and absurd derivatives. Numerous examples to that effect are given in Couturat's excellent monograph, "Étude sur la Dérivation en Esperanto" and de Beaufront's *Bulletin Français-Ido.*

(III) The grammar of Esperanto is so complicated that Esperantists, especially the English and French ones, are unable to write the language correctly as the writer could see from his extensive Esperanto correspondence. The modern languages have restricted the accusative to very few instances. Esperanto has made the obligatory accusative more frequent than the ancient languages. The declension of the adjective according to case and number is another great difficulty and entirely unnecessary as proved by the example of the English language.

(IV) The sound of Esperanto is often repugnant, due to extreme frequency of the sibilants, to almost unpronounceable letter combinations, and to the constant repetition of the syllables aj, ej, oj, uj, ajn, ojn, ujn. Sentences of everyday life often sound like these far-fetched English sentences: "Chichester church stands in Chichester churchyard." "Does she chew chicken giblets?" Here are ordinary sentences which have in Esperanto the same displeasing sound as those far-fetched ones in English: "Chu ci scias chiujn ciajn hodiauajn taskojn?" = (mother to her child) "Do you know all your lessons of to-day?" "Chu shi sciighis chion?" = "Has she learned (been apprised of) everything?" The syllables aj, oj, uj, etc., occur in 30–40 per cent. of the words in some of the best Esperanto writings, as in the following sentences by Dr. Zamenhof himself: "Shi havis la plej graciajn malgrandajn blankajn piedetojn, kiujn bela knabino nur povas havi" = "She had the most graceful little white feet which a beautiful girl could ever have"; "Shi envolvis sin en siajn densajn longajn harojn" = "She wrapped herself up in her thick long hair."

(V) Esperanto has a scanty vocabulary. The completest dictionaries contain only 2629 root words. The Esperantists try to

[11] *Bullet. Français-Ido,* p. 152.

persuade themselves and the whole world—and this appears quite plausible to the unthinking—that a language is so much easier the less root words it possesses. This is a great fallacy, just the opposite being true, as the writer has pointed out in an essay entitled: "How many words are needed?"[12] When the international language does not possess a one-word translation for a conception translatable with one word in a natural language, a writer belonging to the latter has to apply the means of derivation, composition or of periphrasis for expressing that conception, a task that is often very difficult and can be accomplished satisfactorily only by a competent linguist. The poverty of the Esperanto vocabulary has been productive of many absurd word compositions. Having no word for "bull," Esperanto expresses this conception by the composition "bovoviro" which logically can mean only "beef man", a man who is a beef (bovo = beef; viro = man).

(VI) The alphabet of Esperanto contains five accentuated letters not contained in any natural language. The printing of Esperanto works is therefore difficult and expensive, which the writer has experienced in the publication of his Esperanto text-book in 1906.

An artificial language with the dogma of inviolability interdicting every criticism is as little capable of improvement as a natural language. But the weak sides of the latter often represent its nicest features; they reveal peculiarities in a nation's way of thinking. This consideration does not apply in an artificial language and therefore logical incompatibilities can nowise be justified. An artificial language can and must be perfected more and more. Indeed it is just this possibility that has induced many a thinker to concern himself with the question of an artificial language.

The permanent commission of the delegation acted in this sense after assuming the task of developing the project of Ido. It founded an academy and an official magazine, called *Progreso*, and expressly invited general criticism to be published in the latter or submitted to the academy.

It became known later that the project adopted by the committee of the delegation was the work of Marquis L. de Beaufront, the most able of all Esperantists including Dr. Zamenhof. His pseudonym Ido was subsequently adopted as the name of the language which previously had been called Ilo ("Ido" means in Esperanto "offspring"; the root "Il" is built from the initial letters of "internaciona" and "linguo").

Through strictly scientific work lasting for seven years the academy has amplified and perfected Ido considerably. It has, for

[12] *Progr.*, IV, p. 139.

instance, increased the original vocabulary of approximately 3000 root words to nearly 11,000 root words. In 1914 a period of stability of ten years was decreed excluding any further changes during this time. There are only a few important linguistic points which the academy will yet have to consider and settle. Their final adjustment will not produce any noticeable change in the shape of the language arrived at so far.

Two important points distinguish Ido from all its predecessors. Every one of them, Idiom Neutral excepted in a measure, was the creation of one author who, as a rule, was not even a competent philologist. He remained the proprietor of his work and his personal influence was decisive in its further development. Moreover, all previous systems are lacking the principles essential to a logical language which have been discussed above. These principles were unknown before. They have been clearly exposed for the first time by Dr. L. Couturat, the greatest authority on our problem, between 1903 and 1908 in various publications, notably in his excellent monograph "Étude sur la Dérivation" which appeared in the beginning of 1907. In its first edition only a limited number of copies had been printed for distribution among some known students of the problem. The writer had the honor of being one of the recipients. Those principles had been applied in Ido, which was published in the fall of 1907. Furthermore, Ido went over into the custody of the permanent commission shortly after its publication and its perfection was accomplished by an academy consisting of ten competent linguists and advised by some painstaking students of the problem. The predominant influence of one man is therefore absent in Ido.

The characterization of Ido may be summed up in the statement that it conforms to the principles and requirements for a logical IL set forth above. This may be somewhat particularized to contrast Ido with Esperanto more clearly.

(I) There is no arbitrary word in Ido. All its words are a posteriori, *i.e.*, taken from the natural languages. A less international word has sometimes been selected instead of a more international one for valid reasons. Thus the word "hund-o" (= dog, Engl., Germ.) has been adopted instead of the more international word "kan-o" because the latter is needed for the conception "cane". Slight changes of a posteriori words have been made to comply with phonetics and euphony. Thus, the roots "scienc" and "excit" are changed into "cienc" and "ecit", because it is very hard to pronounce the former phonetically.

(II) Strict observance of the principle of unambiguity and that of the restoration of the original sense in restoring the original form

(principle of reversibility) regularize derivation in Ido. The same rule applied in corresponding instances leads to corresponding results whenever new words are derived from given ones.

(III) The entire elementary grammar of Ido is contained in this one simple rule: The main parts of speech are recognizable by 14 characteristic endings. The latter indicate at once the grammatical rôle of every word in a sentence and this is all that is needed to understand a given text in any language as far as grammar is concerned. Indeed, one familiar with two or three European languages can understand a given Ido text even without a dictionary. Besides those fourteen endings he needs to know only the definitions of a few affixes. The adjective in Ido is invariable and the accusative is restricted to the very few cases where it is indispensable to avoid ambiguities. The syntactical rules of grammar are only those required by general logic and common to all well-developed natural languages.

Some object even to this minimum of grammar. They would want the IL to consist of words never inflected. Indeed, there are natural idioms of that character. The very young child does not use inflected words in his talk. A similar phenomenon may be observed in several spontaneous international dialects, such as the Lingua Franca prevalent on the Mediterranean coast, Chinook in the region of the Columbia river, and Pidgin-English on the Chinese coast. Such jargons may be sufficient for expressing the crude thoughts of young children or of adults devoid of any education. But it is a preposterous notion that an IL patterned after those jargons would be adequate to express ideas of Homer, Aristotle, Shakespeare, Newton, Darwin, Goethe, Spinoza, Einstein. The AIL is intended chiefly for making the productions of such geniuses readily accessible to all nations.

(IV) Ido equals Italian with regard to euphony. Of this one may convince himself by reading aloud Ido texts.[13]

(V) Ido has a rich vocabulary of over 11,000 root words and its further enlargement is not limited. The academy is adopting more and more words on the recommendation of competent students who use the language exclusively for scientific works and translations from the natural languages and thereby chance upon conceptions requiring integral (root) words for their expression. The writer entertains the opinion that an author may even render a conception for which the Ido vocabulary has no adequate translation by a word that is neither official, nor semiofficial, *i.e.*, publicly proposed and under consideration, if only that word conforms to the principle of maximum of internationality, or to the a posteriori

[13] See "Comparative texts," Ido, pp. 12–16.

principle when there is no international word for the conception, and provided he indicates in some manner that the word is of his own selection.[14]

(VI) Ido employs the Anglo-Latin alphabet and thus fulfils the requirement that the alphabet of the IL should be simple and not contain any letters with diacritic marks.

Ido can be improved, its further perfection relating chiefly to two points, to the determination of the logical meanings of composed words and some derivatives and to the enlargement of the vocabulary. Regarding the first one two questions remain to be settled: (1) Which is the logical meaning of the substantive derived immediately from an adjective? (2) Which is the logical meaning of a composed word?

The first question has been extensively debated in Progreso by Dr. Couturat and the writer, but is still undecided. The second question is treated by the writer in a long essay where he believes to have proved that certain views advanced by Couturat and another great authority are untenable. The two questions are of general philological interest and their exact solution is of great importance for the perfection of the IL. The final decision regarding them, however, will produce no noticeable change in the shape of Ido arrived at so far.

The vocabulary of Ido can and should be made so rich that the language should have a one-word expression for every conception which can be expressed with one word in any of the principal European languages. This is the writer's answer to the question: "How many words are needed?" (*Progr.*, IV, 139). Only such a vocabulary would impart true facility to the IL. The objection that the student would have to learn too many words is not valid. The English student does not need to know all the words given in the Standard Dictionary.

A most important question pertaining to our problem is this one: Does Ido represent the final solution of the problem of the AIL? Unless this question can be affirmatively answered, students will not concern themselves with Ido when they learn from the history of the problem that so many previous devices have failed. The answer results from the following considerations. The original words of the IL are not dependent upon the ingenuity of the inventor of a new system, but predetermined through the principle of maximum of internationality and the a posteriori principle. Indeed, all the systems a posteriori resemble each other a great deal with respect to the root words. The differences between them are due to those principles not having been carried through with equal

[14] *Progr.*, IV, 139; Raporti al Idoakademio, Nro. VI; Filol. Tem., Nro. V.

strictness in the various projects. Any future device that will apply them exactly will contain the same root words as Ido. Only a few national words may differ. The composed words are given in their forms and logical deductions determine their meanings. The latter do, therefore, not depend upon the arbitrary decisions of authors.

The immediate derivatives in the supposedly new system must be analogous to those of Ido. For the rules of immediate derivation are founded upon the principle of unambiguity, upon its corollary, the principle of reversibility (restoration of the original sense in restoring the original form), and upon the relations between the various parts of speech. These relations can not be arbitrarily invented, nor defined in different ways since they are inherent in the parts of speech. The rules of immediate derivation are, therefore, not free, but predetermined.

The mediate derivation is accomplished through special affixes. The choice of the latter is free, *i e.*, the affixes are more or less arbitrary. An affix, however, applied in a given case, can only be a synonym of an affix used in Ido Since every affix can have but one meaning according to the principle of unambiguity and there is no synonymity between the Ido affixes, the latter can only be increased, but not decreased. For in the second case two ideas distinct and to be distinguished would be fused.

The grammar of the new hypothetical system can hardly be made more simple than the Ido grammar which is reduced to one short rule.

The above considerations lead to the following conclusions under the supposition that the principles of unambiguity and of maximum of internationality are decisive factors for a logical international language. Any system fulfilling the requirements of logic and internationality that may be devised in the future can differ but little from Ido in grammatical respect. It must be almost identical with it in the original, composed, and immediately derived words. Regarding the mediate derivatives it may differ from Ido only through few different affixes. For the majority of the Ido affixes, too, are determined by the principle of internationality. Moreover, the new system may be more complete through the adoption of more affixes than are contained in Ido. An essential difference will therefore not ensue also with regard to the mediate derivatives. Ido, therefore, represents the final solution of the problem of the auxiliary international language.

The need of an AIL is now more urgent than ever. The recent great struggle of the nations has torn asunder three vast empires in each one of which a great language was used by all inhabitants.

These empires are now split up in many independent nationalities each intent upon maintaining its own language in opposition not only to the languages of its small neighbors but also to those of the great nations. Each of the latter, on the other hand, hates the other more than ever and disdains its dearest possession, its language. A neutral auxiliary language will benefit the small nationalities and will relieve the great hostile nations from the necessity of having to employ in their unavoidable intercourse languages that they despise. When true general peace will again prevail in the world, the same language which has served the enemies in their necessary transactions will enable the friends to understand one another properly in all affairs of mutual interest.

CALORIES AND VITAMINES

By Professor B. W. KUNKEL
LAFAYETTE COLLEGE

THE slogan during the strenuous days of the Great War that calories would win it was true in more senses than one. For those at home, it was intended to constrain in the use of food whose value was measured in calories. Neither before nor since that time has the fact been so forcibly taught us. We forgot about pounds and pecks in the enthusiasm aroused over calories. To the armies in the field, however, calories were even more important, not only in furnishing the energy by which the individual could dig into the soil, or charge up earthworks or actually overcome his opponent in hand-to-hand struggle, but also to furnish the propelling force of bullets, the bursting power of shells, and the propelling power of motor trucks and aeroplanes. The energy of explosives like dynamite and fuels like gasoline and coal is measured by the same unit. All along the battle fronts calories were dissipated with prodigal freedom. And the power represented by the calories of food, explosives and fuels won the day. These all-important calories are units equivalent to the quantity of heat necessary to raise the temperature of a kilogram of water one degree centigrade, or roughly a little over a quart of water a degree. The physicists a number of years ago found by experiment that there is a constant relation between the work which a machine does and the heat liberated. There was established the mechanical equivalent of heat: that is, a calorie is able to lift a given weight a definite distance. As calculated by Joule, who investigated the subject first in 1840, a pound weight falling 772 feet raises the temperature of a pound of water one degree Fahrenheit. It is thus evident that these same calories furnish most convenient units for measuring both heat and energy, one calorie being equivalent to 772 foot-pounds.

But while the demand for calories and still more calories was more insistent during the war when an eager and ruthless enemy was at hand, still the demand for calories has confronted man from the beginning and promises to do so through all future ages, for without them man can do no work. He becomes in fact as inert as a corpse. Indeed there is every indication that as populations increase and arable land decreases and the fertility of the soil is gradually washed off into the sea, the problem of supplying the human engine with energy will become more pressing.

Of course, for ages before any of the refinements of calories or chemistry were recognized, our early ancestors cared in their search for food only for a feeling of satiety and the absence of an obvious pain or distress after eating, and painful experience at a very early period of human evolution must have taught them the difference between noxious and beneficial foods. A large store of knowledge regarding these properties of foods must have been acquired through the course of ages and the beginnings of the science of food selection must have been made. But of these unsystematic experiences we are not here concerned in the least. In our discussion of calories and vitamines we will attend only to the scientific discoveries which have added to our knowledge of the true value of foods and the parts which different foods play in the economy of the body.

The first important step in the scientific study of human nutrition was made by Lavoisier in the latter third of the eighteenth century when he showed that the animal heat of the living body was produced by a slow combustion, just as the heat of the candle flame is produced by the rapid combination of the tallow and oxygen, or the heat of the fire is the result of the rapid union of the fuel and the oxygen of the air. It was not till 1894, over a hundred years after Lavoisier, that Rübner with a refined technique and greatly extended knowledge of chemistry and physiology was able to demonstrate that the calories produced by the living animal and manifest as animal heat were equivalent to what might be obtained by the oxidation of the foods consumed. Following Rübner's lead, W. O. Atwater, of Wesleyan University, about 1900 made very important advances by experiments on human beings. The subjects were kept for several days in a closed chamber with elaborate devices for ventilation and temperature regulation and measurement known as a respiration calorimeter. There were also arrangements by which the air entering and leaving the chamber could be sampled. It was provided with a folding bed and a stationary bicycle on which necessary exercise could be taken. The results of many experiments covering several successive days and under different conditions of activity and with different diets, indicated so close a correspondence between the calculated energy of the food consumed, reckoned in calories, and the actual heat given off as to permit the generalization that the income and outgo of energy in the human body are exactly equal when due allowance is made for stores of energy present in the body and indicated by changes in body weight, and that the human body is as truly an engine for transforming the energy of food into heat and motion as the gasoline engine is for the transformation of the energy in the gasoline into heat and motion.

Such experiments as these of Atwater and his associates, based upon observations extending over a number of days and with full grown subjects, naturally emphasized the energy needs of the body and the fuel value of different foods. They also showed clearly by the analysis of the outgo of the subject during the period of observation the needs of the body in respect to the chemical elements, especially carbon and nitrogen, since these are needed in large quantities and from the economic point of view are the most important. With experiments of this kind in mind dietitians naturally sought to furnish diets which met these requirements in respect to calories and carbon and nitrogen. Some foods might be harder to digest and place a greater burden on the intestinal tract to handle them properly, but except for the digestibility of foods it was reckoned that one kind of protein, for example, or one fat was as good as another to meet the bodily needs. The demand of the body for energy which can be introduced only in the form of calories in the food is of course the most insistent demand of the body, for every heart beat and every movement of the smallest muscle means the burning up of some small quantity of living substance which has to be made good if the body is not to waste away. The foods differ from ordinary fuels in one very important respect in that they supply not only energy but also the very materials of which the body is made up and which are discharged from moment to moment as waste products in the excretions.

The most difficult element to supply to the body is nitrogen which can be furnished in only one form and that is, the proteins which are expensive from the economic point of view as well as the physiological, for the excretion of nitrogenous waste places special burdens on the kidneys. Fortunately the nitrogen excretion does not increase at the same rate as the carbon excretion when the activity of the body is increased. It is "protected" as it were so that it is not burned up with the same facility that some other portion of the living substance is which contains no nitrogen.

Specifically, the experiments of Atwater showed that the human body could be maintained in equilibrium with approximately 100 grams per day of protein (such as the curd of milk or the white of egg or the lean of meat) to supply the nitrogenous wastes, and the fuel value of the entire diet must be approximately 2500 calories for a man of average size leading a very sedentary life, or 5000 calories for a lumberman in the northern woods. In making up a practical diet in order that it may contain sufficient energy, or calories, the protein is supplemented by carbohydrates, like sugar and starch and fats, for although the body derives energy from the proteins and could be maintained indefinitely on such a one-sided

diet, it would not be economical or wholesome. Standard diets were calculated for men engaged in different occupations and including various combinations of food. At light work an average man would thus have his nitrogenous and caloric needs met by a diet consisting of 100 grams of protein, yielding 400 calories, 100 grams of fats yielding 900 calories, and 500 grams of carbohydrates yielding 2000 calories. Such a diet, with the usual combinations of flavorings and variety with several quarts of water (which would be mixed with the food to a great extent) and with sufficient roughage to give it bulk and decrease its concentration satisfies the appetite. It is well balanced and when obtained from natural sources, with the naturally occurring impurities and unknown constituents which defy the chemist's skill to detect, is adequate. It corresponds rather closely with what has been found by long years of experience to satisfy a normal appetite. This balancing of our diet is practiced instinctively by our preference for a little fat with our meat, for bread and butter rather than dry bread, for gravy with our potato. The combination of proteins, fats and carbohydrates just given may be regarded as a typical allowance to meet the bodily needs. In those cases where the economic conditions allow the appetite to be satisfied readily, this may be taken as a kind of standard diet. There are of course individual differences as well as racial ones, but these concern more particularly the sources of the food than the ultimate analysis of them. The Esquimau rarely partakes of carbohydrate food because of the scarcity of vegetation in the Arctic, but he makes up for this deficiency with great quantities of protein and fat which he obtains from the fish and other animal food upon which he depends. The Oriental, oppressed by poverty in a densely populated land, regards meat of the most inferior quality as a treat rarely indulged in, for carbohydrates are almost the only foods that come within reach of his constantly empty pocketbook. But Americans and Europeans, having the wealth necessary for a moderate degree of well-being, show rather insignificant variations from the normal.

Within the period covered by the experiments with the human subject in a respiration calorimeter, there were no noticeable differences in the effects of foods when due allowance was made for the approximate chemical composition. One protein seemed just as useful to supply the wastes of the body as another. Wheat bread or corn bread, meat or cheese, olive oil or butter apparently could be used indifferently. Butter, to be sure, has a certain quantity of water and salt which the olive oil does not, but when this difference was taken into account the two seemed to be equally valuable to meet the bodily needs. Corn and wheat have quite

different compositions, but the several constituents of each were supposed on the strength of these experiments to be equally valuable. In other words, up to a comparatively few years ago it was supposed that the percentage of protein, carbohydrate and fat in a given food was all that was necessary to know about it from the dietetic point of view. This view was characteristic of what we may call the dietetic age of the calorie. To be sure, it had been known for years that there were some proteins like gelatine which could not replace entirely in the diet the proteins which occur naturally in foods in various combinations. It contained nitrogen which could be used by the body and could replace to a large extent the more expensive proteins, but curiously enough animals fed on this one substance yielding nitrogen soon sickened. Long before there was very much of a science of nutrition or physiological chemistry, in the days of the French Revolution, when meat was so expensive as to be quite beyond the reach of all but the wealthy, and milk and eggs were quite as expensive as meat, the savants of the French Academy tried to substitute for meat gelatin which they manufactured cheaply from bones and tendons which were in themselves unfit for human food. This substitute was tried on hospital patients but the effects were not all that were desired. The gelatin was digested readily, and for a time seemed to satisfy the needs of the patients, but in the absence of other nitrogen-containing food they grew so uniformly sicker and sicker after a time that it became apparent that the diet was at fault. Gelatin accordingly came to be regarded as a useless addition to the diet and for a long time was most unjustly condemned. Since the French Revolution there have been other attempts to make artificial foods to take the place of the vegetables and meats and milk and eggs which mankind has lived on for so many centuries, but until very recent years they have been uniformly unsuccessful. Foods specially purified by the chemists, though not those that bear the label of the pure food law, could not take the place entirely of the foods which nature prepares in the great out-of-doors.

The failure of animals to survive long on a diet composed of chemically pure constituents rather than the mixtures of different proteins, carbohydrates and fats which are found usually in the products of the field puzzled physiologists for many years. In fact, it has only been during the last ten or fifteen years that the defects of gelatin and other semi-artificial products as foods have been accurately understood. To-day we know that few proteins singly can satisfy the nitrogenous needs of the body.

Before we leave the age of calories, however, reference must be made to the experiments conducted by Professor Chittenden at

Yale. Influenced by Horace Fletcher's propaganda on the advantages of a low protein diet, Chittenden undertook a prolonged experiment on a large scale to test the validity of the conclusions of the physiologists that at least 100 grams of protein per day are necessary to maintain the body in nitrogenous equilibrium. Is it necessary to burden the body with the disposal of so much nitrogen per day as the dietitian had supposed? Chittenden experimented with a squad of soldiers who were widely advertised in the newspapers. His results seemed to indicate that the standard diet which Americans and Europeans had adopted more or less instinctively and which had been accepted by experimenters generally would have to be revised. A dozen or more normal men during a period of six months living on a low protein diet equivalent to about one half of what was usually regarded as the minimum seemed to suffer no evil effects. He subjected them to measurements and severe physical tests at various times during the period under consideration and found that they remained in the best of condition with no appreciable loss of vigor or strength.

For a while it looked as if the quantity of protein which was habitually consumed was greatly in excess of what the body needed and that great economies could be effected both from the monetary and physiological points of view by the general adoption of the low protein diet. The calories received a boost accordingly, and the emphasis was again placed on the all-important factor of fuel value of food. In spite, however, of the vindication of the low protein proponents it is exceedingly interesting to see how slowly the new dietary régime has been accepted by the populace generally. The evils of an excessively rich protein diet were emphasized by these experiments and some rationalizing of the diet resulted, but the long established habit of a moderately rich protein diet persisted, the flesh pots clamored loudly and the appetite for the approximately 100 grams of protein a day was so insistent that it would seem to indicate a fundamental need of the body. To what may we attribute this well-established habit? Is it simply the effect of a pernicious habit which is as persistent as it is pernicious? Is it simply a manifestation of the perversity of human nature? The answer to these questions has not been forthcoming after many years. In fact, it was not until the experimenter was in a position to test the effects of single purified proteins on growing animals extending over prolonged periods that light was thrown on these problems.

The problem of the effects of single purified proteins on growth and health was taken up by the two American physiological chemists, Osborne and Mendel, at New Haven. Their purpose was to

study the effects of diets which were ample in their calories and in the quantity of the necessary chemical elements to meet the needs of the body, but which differed from each other simply in the nature of the protein which was supplied. Chemically purified proteins in place of the mixtures which occur with few exceptions in natural products were fed. In this way it was possible to determine whether one protein is as effective as another in satisfying the bodily needs. As already indicated, it had been known for a century that gelatin was incapable of taking the place of proteins entirely. What is there about the gelatin which renders it unfit to supply all the nitrogen which is needed? Is one protein as effective in preserving the nitrogen balance in the body as another? These were questions which the experimenters attempted to answer. They chose white rats as their subjects because of their convenience in the laboratory. They do not require vast quantities of food and they mature and reproduce rapidly, so that growth can be quickly determined and the effect of the restricted diet can be determined on successive generations. In these animals, the female bears her first litter when only 120 days old, and by the time she is fourteen months old may have had as many as five litters. The span of life of a well-nourished rat is about thirty-six months, so that in three years the observer can follow the course of life of an individual corresponding to a period of ninety years in the human life span!

As early as 1908, it was found that growth did not take place in the white rat with the same rapidity when single purified proteins were used exclusively in the diet, regardless of how much was fed or how abundant the diet in general might be. One rat which was given an ample diet in which the only protein was the casein of milk, supplemented with a well-balanced ration of sugar and starch and fats and inorganic salts, increased steadily in weight from 60 grams to 270 in the course of 140 days. Another rat fed on the same diet, except that one of the proteins of wheat took the place of the casein, gained only 40 grams in 240 days. Such a gain in weight over so long a period would be about the same thing as a man's gaining say 20 pounds between the ages of one year and twenty! A third rat treated similarly, except that the principal protein of corn took the place of the casein, actually lost 40 grams in less than 90 days after having been changed from a mixed protein diet to the experimental one.

Results like these showed unquestionably that calories alone were far from being the only requirements for an adequate diet, even when they were administered through foods containing the requisite quantities of protein, carbohydrate and fat, especially for a growing animal, and that far more subtle factors play a large

part in satisfying the physiological needs of the body. These experiments called attention especially to the differences in the "building stones" of which the proteins are composed—the amino-acids. These are rather complex compounds, although marvelously simple in contrast to the proteins themselves. They can be obtained from proteins by certain analytic methods which bring about their decomposition to simpler bodies.

In the chemist's shorthand method of expressing chemical composition, one of the very simplest of these amino-acids has the formula $CH_2 \cdot NH_2 \cdot COOH$, which means that it is composed of the elements carbon, hydrogen, nitrogen and oxygen in the proportions indicated by the number of atoms of each—two of carbon, five of hydrogen, one of nitrogen and two of oxygen—and that these atoms are definitely arranged so that on analysis some of them seem to be more closely held together than others. This is also indicated by the arrangement in the formula and the separation of the whole compound into three separate radicals. There are some eighteen of these amino-acids which the chemist has derived from proteins, but as they all bear quite unusual names, it is hardly necessary to enumerate them here. Their "nickname" of building stones of the proteins is in allusion to the fact that they apparently enter into the composition of the proteins like stones in a wall. The arrangement of the stones may give a particular pattern to the wall, and a selection of stones may make a wall of specific material. There is every indication that in the digestion of protein food the molecule is broken up into the separate amino-acids and in assimilation these same building stones are brought together in different patterns and in different proportions, comparable to the formation of words by combining syllables in different ways and repeating them varying numbers of times. We have to think of the building of the living substance, not like architectural construction from sand and cement and wood and iron, for example, but from elaborately shaped blocks, each of which may contain definite proportions of the elementary building materials.

This idea was confirmed by the fact that proteins which in their purity were inadequate might be made thoroughly satisfying by adding to them in the diet the amino-acids which they were lacking in their make-up.

A new factor is thus seen to enter into the problem of diet. Not only must there be a certain amount of protein furnished, but also it must yield on decomposition or digestion the necessary amino-acids. The proteins are not for this reason equally useful to the body. Some of the amino-acids are required in very small amounts to make good the wear and tear of the body while others must be

provided in much larger quantities. It is especially in the growing animal in which new material has to be constructed that the need for these particular building stones is most keenly felt, for once these structures are formed, the wear and tear does not affect them so severely. In the ordinary varied dietary, especially if there is sufficient milk, there is little danger of a deficiency of one of the necessary amino-acids. This deficiency is manifest only when the diet is very monotonous with reference to the proteins and when they lack some of the required amino-acids.

In the light of what we now know about the products of decomposition of gelatin, for example, it is evident that its failure to replace satisfactorily ordinary proteins lies in the fact that it lacks two important building stones which the body can not put together and which occur in nearly all ordinary proteins. The inadequacy of gelatin may be likened to that of a font of type in which, for example, the letters *a* and *t* are missing. The compositor may set up a few words perfectly without being aware of the imperfection of the font, but pretty certainly before much progress has been made these letters will be demanded by the copy and the work will be held up until the missing letters are furnished. As a matter of fact, experiments have shown that if the missing amino-acids supplement the gelatin, the diet is satisfactory.

It may be worth suggesting that a possible defect in the extremely low protein diet may lie in the undue reduction of the factor of safety in respect to these constituents, so that the instinct to increase the protein consumption when the supply can be procured readily may be to prevent this serious defect.

While most of the amino-acids have to be furnished to the animal body ready made, there are some relatively simple ones, like that whose formula was given above, which can apparently be manufactured directly in the body: at least, growth is not retarded when the protein diet is deficient only in regard to it. On the other hand one of the more complex amino-acids that is lacking in the protein of corn can not be built up in the body. As a result, maize, when used exclusively as a source of protein, is inadequate. The protein of milk affords an abundance of this constituent and is one of the most important promoters of growth that we know. To-day, the student of nutrition keeps in the foreground the fact that it is not nitrogen in an uncombined state that is utilized by the body, but in the complex amino-acids.

So far, however, in our discussion of diet, nothing has been said of the vitamines which within the last few years have come so strongly to the fore in the field of dietetics. The diet, to be adequate, must represent sufficient calories to supply the energy of the daily and momentary activities of the body. It must also contain

certain amino-acids in order that none of the necessary building stones out of which the complex proteins are made are lacking. And there must also be present certain bodies known as the vitamines. We still know practically nothing in regard to the composition of these bodies and only in a general way may they be said to act as regulators of chemical activity in the body without which a large number of nutritional defects very promptly put in an appearance. They were discovered more or less inadvertently in experiments designed to test the value of isolated and purified fats upon growth and nutrition.

About these regulators of metabolism we still know little, so little in fact that they have been given such equivocal names as fat-soluble A, water-soluble B, and water-soluble C. Deficiencies of these bodies in the diet lead to certain well-known diseases which yield to treatment by supplying the deficiencies. Scurvy, which caused terrific suffering in the olden days among mariners who lived exclusively for months on biscuits and salt pork, was relieved almost immediately by adding a liberal allowance of fresh meat or vegetables. Beri-beri which is a disease common among the poorest classes in the Orient whose food is principally polished rice and fish is relieved by the addition of an extract of the polishings of the rice. Pellagra is another disease brought on by a one-sided, monotonous diet which yields readily to a change of food.

Experiments in which foods purified artificially have been employed have invariably led to symptoms like certain of these deficiency diseases.

It was not till 1912 that light began to dawn on this problem of why thoroughly refined or purified food was inadequate through the work of McCollum. Rats were again the subjects for the experiments and a diet which consisted of purified casein, milk sugar, starch, fats of different kinds and mineral matter similar to that which is represented by the ash of milk was used. The proportions of these different ingredients were carefully worked out and their purity was very high. In these experiments it was observed that butter fat permitted normal growth to take place while the substitution of lard, olive oil or other vegetable oils interfered with the normal rate of growth or inhibited it altogether. In spite of the fact that the different fats fed seemed by chemical analysis to be pure, one was adequate, the others mentioned were distinctly inadequate. Three years earlier Stepp found that mice could be reared on a ration of bread made with milk, but died shortly when fed on the same bread which had been extracted with alcohol. The alcohol dissolved something out of the bread which was essential for the well-being of the animals. Incidentally it may be noted that the addition of the substances dissolved out by the alcohol to the ex-

tracted bread rendered the latter capable of supporting life as it did originally. In other words, the alcohol had removed without altering some constituent of the ration. The analysis of this extract did not disclose anything extraordinary or unexpected, but when these known substances were added to the extracted bread it remained inadequate. The only conclusion to be drawn from these results was that there must be something necessary for the support of life which is soluble in alcohol but in such small quantities as to escape detection by ordinary chemical means.

It remained for McCollum and his associates to demonstrate a constituent of butter fat or cream which is necessary for growth as well as for the maintenance of life in mice beyond a period of a few weeks. We are still unable to detect this substance chemically so that it is impossible to determine its chemical properties. It is, in fact, only by testing foods specially purified or specially separated constituents of the food on living animals for a longer or shorter period that its presence can become known. McCollum was unable to isolate this necessary regulator of the life processes but in as much as it occurred in fat, he gave it the very equivocal name of fat-soluble A, and to this day this unknown substance bears that name. So powerful is it in its action that one five-hundredth of a milligram has an easily seen effect on an animal, and this is true when in a most impure condition, for the chemist has so far been unable to isolate it in its purity.

This fat-soluble A, which is one of the few vitamines whose presence is definitely known, occurs also in that exclusive food of the developing chick, the yolk of the egg. It is abundant also in the fat that is deposited in the liver. Cod-liver oil owes its wonderful effect on growth and development to this unknown constituent. It may be substituted with impunity in the laboratory for butter. It also occurs in the leaf vegetables like spinach and lettuce. On the other hand, certain vegetable oils like olive oil and almond oil proved quite as ineffective in keeping rats healthy as did lard. This, of course, does not mean that vegetable oils and lard are improper foods or of little value. Far from it, they are very rich in heat units and satisfy hunger quite as effectively as the highly esteemed butter fats and the much despised cod-liver oil. The butter fats contain this something, fat-soluble A, in very small quantity, which regulates the metabolic activities of the body and supplies something without which the body can not survive.

McCollum found still another vitamine in his experimenting which is just as necessary for the proper maintenance of the body as the fat-soluble A. The abnormal conditions which result from prolonged feeding on polished rice and which together constitute the disease beri-beri in the human subject are not relieved by the administration of butter fat. The addition of skim milk in this

case relieved the symptoms which the butter fats failed to relieve. The milk sugar of milk was then used in place of the skim milk and as long as this was not purified too highly chemically, it served to relieve the unfavorable symptoms. The conclusion was inevitable that there was something in the skim milk necessary for health but which can not be isolated in pure form from it. To this unknown body he gave the name of water-soluble B. This substance occurs very widely distributed in natural foods. It is soluble in water so that in boiling foods it is extracted and lost if the fluid is discarded. Vegetable soups, boiled cabbage with the liquor, milk, the outer husks of cereals, and above all, yeast, are rich in water soluble B. In fact, from 200 pounds of yeast, one twelfth of an ounce of a product has been obtained which is so active in relieving the symptoms of beri-beri in pigeons that one fifteen-thousandth of an ounce has marked effect in a few hours.

This vitamine is so widely distributed that it is unnecessary to take special precaution to insure enough. It is not stored in the body against the day of need, so that small quantities must be eaten fairly constantly to keep up the vigor of the animal. It is only the over-refinement of the culinary art which dispenses with every portion of the food which is difficult to masticate or which is in the nature of "roughage," which is likely to lead to a deficiency of this compound in the diet.

A third vitamine has been demonstrated, different from the other two in its curative or corrective effects but still unknown as to its composition. It is particularly abundant in succulent vegetables and fruit in the fresh condition, especially oranges and lemons. It also occurs in milk, provided that the cattle have had a diet that was ample in this constituent. It is destroyed by heating and drying unless the material is very strongly acid; desiccated cabbage and potatoes apparently lose much of their effectiveness in relieving the symptoms of scurvy which follow a deficiency of this compound.

So far, only these three vitamines have been demonstrated. Their action seems to be quite definitely regulating, since the absence of one or the other leads very promptly to pathological conditions.

From what has just been said in regard to calories and vitamines, the outstanding conclusion is obvious, that in the long years of human evolution the appetite has become most accurate in determining the needs of the body and that the body has been most accurately adapted to the food stuffs which occur in nature and which have not been purified by artificial means. The advances in dietetics have not succeeded in reducing the complexity of the problem of supplying adequate food, but most definitely have shown that many factors previously unknown are essential to the maintenance of health and vigor.

OCEAN LIFE

By Professor W. K. FISHER
HOPKINS MARINE STATION OF STANFORD UNIVERSITY

MAN'S earliest interest in the sea was probably connected with his stomach, but there is evidence that from very ancient times the ocean has served him equally well in feeding the spirit. It has been an unfailing source of wonder, second only to the stars and the infinity of stellar space, and it has supplied a galaxy of mysteries which will rescue biologists at least from any danger of ennui. Its hordes of queer creatures—the multitudes of sponges, jelly fishes, anemones, corals, sea stars, crabs and other unfamiliar animals—never fail to awaken our curiosity. Our existence, even, is bound up with the sea, for terrestrial life is possible only by reason of the water, which, originally derived from the ocean, falls upon the land and returning in streamlets and rivers repeats the never-ending cycle. More directly we regard it as an inexhaustible source of food, for we take from it enormous supplies of fishes, oysters, clams, crabs, lobsters and fry of lesser value.

The sea subtracts as well as adds. If the cod, herring and halibut yield millions to commerce, the lowly shipworm, a bizarre mollusc, bores unseen into harbor piling and causes wharves and warehouses to collapse by its diabolical industry. New York harbor and other eastern ports are threatened by an attack of this pest, which has already inflicted on San Francisco a property loss estimated at fifteen million dollars. The shipworm or teredo when very tiny enters the wood through a hole hardly bigger than a pin. The bores become rapidly larger as the animal grows, until they reach the size of a leadpencil. Unprotected piles are soon riddled and often the first intimation of the molluscs's presence is the collapse of the wharf or warehouse. The species which is particularly to be feared on the Atlantic coast reproduces at a prodigious rate, is able to live in brackish water and appears able to thrive in harbor water carrying heavy loads of sewage. Where teredos are now established the destruction is so great and the means of protection so expensive that they are responsible for from one fourth to one third of all the costs of loading and unloading vessels at wharves—a bill which, of course, is paid by you and me.

Whether we are concerned with whales, cod or shipworms, any conception of the life and background of these creatures necessitates an appreciation of a fact easily overlooked—that the ocean

consists of salt water. For all the varied properties of water (or rather of a dilute solution of the earth in which common salt predominates) are brought to bear upon every animal and plant, however great or small, that lives within it. Heat, light, oxygen, moisture are no less essential to oceanic than to terrestrial animals and plants. In addition, the ability of tiny organisms to maintain their proper level in the sea is profoundly affected by changes in the density of water, and especially by fluctuations of its internal friction or viscosity, for water is more sticky when cooled just as molasses and other fluids are. To this attribute of water—and the subtle adjustment thereto of the microscopic atomies of the ocean—is linked the welfare of practically all oceanic animals. This leads us to the meadows of the sea and the ultimate source of that organic energy which is the title of this article.

For what, after all, are animals and plants, if not self-sustaining and self-perpetuating expressions of energy? This energy, so physicists suggest, is jarred loose during atomic disturbances within the sun—electron displacements, induced, it is believed, by unthinkable heat and pressure at the core of that fiery maelstrom. Shot inconceivable distances into stellar space, a very small portion of this vagrant energy is picked up by the green vegetation of the earth—by the plants of the land, and their equally important but unseen microscopic prototypes of the sea. In the presence of sunlight, by virtue of this radiant energy, the green coloring material in plants breaks down carbonic acid and, adding water, builds up the sugars and starches, so desperately essential to every animal. In addition, plants use for the maintenance of their basic life-stuff, called protoplasm, simple compounds of nitrogen (previously prepared by bacteria), phosphorus and sulphur, which in the form of nitrates, phosphates and sulphates are dissolved in water and reach the plant by absorption into its tissues.

Animals can not use these relatively simple compounds. They require the highly organized proteids, the sugars, starches and fats, and these can be elaborated from their constituents of the air and soil only by plants. Hence, no plants, no animals. A picture of a world suddenly deprived of vegetation is lugubrious. The plant-eating animals would first perish, followed by their carnivorous enemies. The organic remains would cover the earth and charge its waters, at last falling prey to the denitrifying bacteria until reduced to the inorganic materials of air and soil, when the bacteria would themselves succumb, and the world would be dead.

Energy, then, is stored by plants, and the great reservoir in the ocean is not the conspicuous seaweeds, important as these are, but those inconceivable billions of microscopic diatoms, coccolithophores, dinoflagellates and related forms which collectively com-

prise the ocean meadows. In these floating pastures, sometimes termed plankton, the tiny diatoms with siliceous shells of exquisite form and sculpture comprise the grass. They are so small that only the largest can be seen by sharp eyes. Yet these are giants to the coccolithophores, another group of important and very ancient algae with limy shells. Three to six thousand of the tinier species may lie side by side within an inch.

The newer biology of the ocean is greatly concerned with the distribution of these energy-fixing organisms and their associates of the plankton, for it is this permanent stock of sea-soup which provides food for all the animals economically important to man. They are by no means equally distributed, for the ocean no less than the land has its deserts. Among the diatoms, numerically the most important, there are clearly marked arctic, temperate and torrid zone forms. They are more abundant in cold than in warm seas, and probably owing to a rich supply of organic detritus washed from land, they form a thicker sea-soup near continents than in mid-ocean. Their areas of greatest abundance coincide therefore with valuable fisheries—those of the cod, herring, menhaden, sardine, mackerel, halibut and others which are located in cool or cold water near land.

The transformations which the energy of the sun may undergo between the diatoms, let us say, and the larger animals vary widely in number. The commissary chain may be surprisingly short. The sardine and menhaden feed directly upon diatoms and microscopic, plant-like animals, the dinoflagellates, which are filtered from water, taken into the mouth, by numerous overlapping rows of delicate filaments attached to the gill-arches.

The next link in the chain is furnished by the prodigious swarms of wee shrimp-like copepods, and other minute plant feeders of the animal plankton, which bridge the gap between diatoms and larger creatures, including the young and adults of many fishes. They are the meat of the sea-soup. Sixty thousand have been found in the stomach of a single adult herring, while three thousand were taken from a herring only two and six tenths inches long. Together with minute molluscan pteropods they form the chief food of the huge arctic right whale and the boreal blue whale, which screen out the minute organisms by means of finely fringed plates of "whale-bone"—a device mechanically very similar to that of the sardine and menhaden.

An analysis of this mixed plankton gives some idea of the nutritive values of the organisms. The figures, when reduced to roundness, are in this order: One copepod equals one hundred and twenty-five dinoflagellates (Peridinium) equals two thousand five hundred diatoms. A rich vertical haul through sixty feet of water

taken in Kiel Bay, contained two hundred and seventy-three million diatoms, eleven million six hundred thousand dinoflagellates and ninety-six thousand copepods.

The existence of the microorganisms of the plankton depends upon their ability to keep afloat within reach of solar light, and many are the devices for increasing buoyancy. One of the commonest is the storage of oil, but perhaps the most interesting are those which enlarge their surface, or size of projection, transverse to the direction of sinking. As every one knows, a thin plate sinks faster edgewise than flatwise. Copepods develop feather, plate, or rod-shaped appendages, and many diatoms have suspension organs in the form of hairs or the cells are very much prolonged or are united in linear colonies. Since changes in temperature profoundly modify the buoyancy of tiny organisms, because cold water offers more resistance than warm, many diatoms can adapt their floating forms to seasonal fluctuations. Distinct summer and winter phases are produced, the former having usually thinner cell-walls and a more slender structure. Their excess weight is reduced, though at the same time their surface is comparatively larger. Kofoid has shown that certain dinoflagellates (Ceratium) are able to regulate their floating power, for when they enter colder or warmer layers they can shed portions of their horns or grow longer ones at will. They also have the power of discarding layers from the cell-wall, which normally increases in thickness during the life of the animal.

The conservation of the food supply of fishes is quite as important as measures for the protection of the fish themselves. The latter are not likely to be exterminated by ordinary operations, because these will cease automatically when the fisheries become too depleted to pay; and there will ordinarily remain an abundance of seed stock in inaccessible places. The food question is one of linkage of organisms, the ends of the chain being often as apparently unconnected as the cats and the clover in Darwin's famous story.

The three most prolific sources of fish food are the sea-soup, dead remains in the mud of the ocean floor and the growth of seaweeds and eel-grass along shore. While few fish eat microscopic organisms directly, and still fewer browse on seaweeds or mud, the food chain includes creatures which get their sustenance from these supplies. Steam trawling, where vigorously prosecuted, as in Europe, grazes the very soil of continental plateaus,, ruining bottoms that are fittest for breeding, destroying food and entailing a wastage that Prince Albert of Monaco estimated to exceed fifty per cent. of the edible produce sought. For we must include in this summary valuation the young killed by the drag-net as it passes, and those which reach the ship in such condition that they are useless. Whenever such operations become a menace the logical solu-

tion is the establishment of closed areas. In those parts of the sea where the war prevented fishing for a number of years, plenty of fish are now available, some of a size unheard-of for thirty years. We must, then, guard the sources of fish food. It is distinctly unwise, for example, to pollute our California littoral with crude oil, as has been done for years. Injury is difficult to prove until after the harm is done.

Great advances have been made in recent years in the study of the action of marine organisms upon one another. The general program of the International Committee for the Investigation of the Sea, with its mapping of breeding grounds and the movements of fishes and their young, is a very distinct advance in cooperative work between biologist and oceanographer. Our own Bureau of Fisheries has for years been collecting information concerning the life history of economically important marine animals, to such good purpose that commercial fisheries have profited very many-fold the cost. The North Pacific is still a little known body of water, and we can not use analogies drawn from the Atlantic. It must be explored intensively, for increasing population on its shores will inevitably bring greater demands upon its resources. So far as the United States is concerned, this is the most important immediate task in oceanic biology.

The new world of the deep sea was practically discovered by the Challenger Expedition (1872–1876), which, as Murray remarked, may be ranked as a Columbus voyage in the history of biology. Hitherto the great depths were believed to be lifeless. Now we know that the greatest depths are inhabited.

The average depth of the ocean is two and a half miles. That portion deeper than two miles comprises more than half the superficial area of the earth, or about one hundred millions of square miles. There are many great depressions from three to five miles deep; the greatest, near the Island of Guam, being sixty-six feet less than six miles. The weight of such a mass of water upon the vast, frigid, black realm of the abysses is impossible to sense, for if pressure per square inch increases approximately a pound for every two feet, the ordinary depths of two miles carry considerably over two and a half tons to the inch, and the bottom of the greatest deeps, six to seven and one half tons—certainly pressure enough to account for the soft permeable bodies of abyssal animals.

The sun's heat is lost in the upper layers of the ocean, and by vertical currents reaches a depth of only about nine hundred feet, a mere scratch on the surface. The abysses are intensely and uniformly cold, often near the freezing point of fresh water, and below thirty degrees Fahrenheit in the polar seas. This icy water, rich in oxygen, is chiefly derived from the Antarctic, whence it creeps at

intermediate depths, slowly counter clock-wise, around the great ocean basin, a titanic if feeble whirlpool from whose inner border currents sink into the greatest depths. To a less degree there is a similar flow from the Arctic, possibly drawn into the larger Antarctic current. Interesting confirmation of the southern origin of deep Pacific water has been furnished by A. H. Clark's work on the distribution of certain crinoids or sea lilies. The writer has found similar evidence in several genera of sea stars.

The ability of water to absorb heat rays applies also to other radiant energy from the sun. Light disappears in the upper layers of the sea, the red and orange yellow rays being the first to go, then the green, blue and violet. A Swiss naturalist, Hermann Fol, in a diving suit in the clear waters off Nice, France, observed that at only thirty feet the light disappeared quite suddenly in the afternoon, long before sunset. At one hundred feet, the light was so dim that he could gather animals only with difficulty, and he noticed that dark red animals appeared black. The depth to which light penetrates has been tested by lowering highly sensitive photographic plates. Some work by Bertil and Grein is very exact. If we place as 1000 the amount of light radiation reaching one meter down, at 5 meters there remains but 3.7 of red, 2.5 of orange yellow, 230 of green, 450 of blue, and 866 of violet blue. At 50 meters red rays are reduced to 0.0021; at 100 meters, 0.001 of the orange yellow remains, and at 1000 meters, 0.0003 of green, 0.0001 of blue and 0.003 of violet blue; at 1500 meters, violet blue is reduced to 0.00001.

For practical purposes light does not extend in very clear water much below fifteen hundred feet, and that appreciable to the human eye probably does not exceed two hundred feet. The submarine day decreases very rapidly, with depth. Some experiments at Madeira, in March, indicate for sixty-five feet, eleven hours; for one hundred feet, five hours, and for one hundred and thirty feet, only fifteen minutes, at about two o'clock. This is of interest in connection with the daily vertical migrations of most open-sea animals. Multitudes follow the twilight zone up and down at evening and morning, while others, rising only at night from the deeper intermediate regions to within a hundred and fifty feet of the surface, spend their lives in a perpetual vertical oscillation, the period of which is twenty-four hours. These creatures, often uncanny in appearance and scintillating with lights, know neither the top nor the bottom of the sea, and are adapted to withstand enormous variations of water pressure.

Monotony is strikingly characteristic of the eerie deeps, which well-nigh all types of marine animals, from microscopic forms to fishes, have made their abode. There are no seasons—uniform

winter, endless night. Yet with a perfectly uncanny adaptability, protoplasm flows as serenely in temperatures sometimes below the freezing point of fresh water as in limpid pools of tropic reefs. There are no bacteria and no living green plants. A ceaseless drizzle of small organisms that have succumbed in the ocean meadows (perhaps miles above) slowly settles like gentle snow on the ocean floor and provides food for multitudes, which in turn fall prey to others, in thousands of nutritive cycles.

Deep-sea animals are much more delicately constructed than their shallower water relatives, many having bodies thoroughly permeable to water. Glass sponges of exquisite delicacy live successfully under pressure of many tons to the inch, because the whole body is open to the water. Sedentary forms, such as frail, phosphorescent sea pens, arborescent polyps and tall sea lilies or crinoids, rear themselves above the mud, while quaint spiny crabs, with spindly legs and egg-shell bodies, vie in slimness with the pycnogonids, grotesque "all-legs," neither spiders nor crustaceans. In the branches of these miniature forests of tree-animals dwell thousands of different species of all sorts of types. On and within the ooze are other myriads—bristling sea urchins and sea stars, sea cucumbers, inconceivably delicate shrimps, molluscs and worms. Prowling fish, of unconventional design and voracious appetite, feed upon this abundant fauna.

When we ascend a great mountain the vegetation and animals change with increasing altitudes. Broad belts of approximately equal temperature have a uniform assemblage of plants and animals. So it is when with the long arm of the dredge we follow the bottom into deep water. The lighted zone along shore teems with life unlike that at one hundred fathoms, while at five hundred fathoms still another world is seen, and so on with increasing depth. That temperature is the most important factor seems likely, for at five hundred to one thousand fathoms off California are found relatively shallow-water subarctic types.

Our knowledge of abyssal animals really began with the *Challenger* Expedition under Wyville Thompson. From 1872 to 1876 this vessel covered sixty-eight thousand, nine hundred nautical miles and brought home results which have required forty huge volumes to record. Then came the American *Blake*, under Agassiz and Sigsbee, followed in 1883 by the fisheries steamer *Albatross*, whose many cruises, to mention only the Pacific, have extended from Bering Sea to Cape Horn, Polynesia, the East Indies and Japan. The care of her enormous collections has been one of the many duties of the National Museum, ably executed under financial handicaps, and to the cooperation of specialists we owe the high

place which this country now holds in the development of marine biology.

Europe has been very active, nearly every maritime country taking part. The late Prince Albert of Monaco devoted thirty-seven years to submarine exploration, first with the *Hirondelle,* and since 1898 with the second *Princesse Alice.* To him is due much of our knowledge of the great intermediate depths. He founded the Oceanographic Institute at Paris and the Oceanographic Museum at Monaco. Carved in large letters on the frieze of this building are the names of all the more important vessels which have contributed to the science of the sea—*Albatross, Blake, Gazelle, Investigator, Novara, Vitiaz, Belgica, Talisman, Valdivia, Washington, Vega, Fram, Princesse Alice, Hirondelle, Pola, Challenger, Buccaneer, Aurelia* and *Ingolf.* To these should be added the recent Norwegian ship, *Michael Sars,* which has done splendid work in the North Atlantic.

The production of light by animals has always possessed a peculiar fascination for humans, and it is one of the problems of the deep sea. It is exhibited by creatures of all scales of complexity, by sedentary forms and by swimmers. In the wide, lightless reaches far above bottom we meet that vertically oscillating fauna, which as regards the fishes and cuttlefishes, is characteristically luminous. Clearly defined and localized light-organs of glandular origin sometimes possess a lens and reflector, and occur in queer places, inside the gill-cavity, on the end of the tail, or on the eyeball of devilfishes. There they emit an ultramarine, clear blue, pearly white, greenish or ruby light. The tiny lanterns are scattered, or gleam in straight rows along the sides, like illuminated portholes of a fairy ship. In bottom animals, luminosity is associated more often with surface slime than with localized organs, being caused, as in most other cases, by oxidation of a special compound.

Does animal light afford a dim glow in the abysses? Why does the cuttlefish illuminate its gill-cavity? Why in certain others is the disposition of luminescent organs different in the two sexes? Why does the angler have a lighted bait on his rod? The best we can do is to guess; but if light is useless, why do many abyssal fishes, cuttlefishes and crustaceans have well-developed eyes? What shall we say of the microscopic Noctiluca, dinoflagellates and tiny crustacea which coruscate and gleam in the ocean meadows so brightly that they guide fishermen to feeding shoals? And not only adult animals but larvae, embryos and even eggs are known to be luminescent.

If we are in search of underlying purpose, a wealth of mystification will follow even a cursory examination of the rich reds, oranges, yellows, brown-purples and purple-blacks that predomi-

nate in the colors of the abyssal population, most of which are untouched by the ghost of a solar ray. In the squashy, frigid ooze, a mile or more down, dwell gorgeous red and purplish sea pens, orange, rose and violet sea cucumbers, yellow, orange, red or purplish sea lilies, rose, red and salmon sea stars and crabs, purple-brown fishes Far above them, at various levels in the black 'twixt world swim curious chocolate and red jellyfishes, black fishes with an extraordinary dental equipment, mirror-sided, goggle-eyed fishes, glass-clear ellarvae, blazing red shrimps and a host of colorful cuttlefishes twinkling with lights.

In contrast to these heavy tints are the delicate colors or lack of color of animals living at or near the surface. Every sailor is familiar with the sea-blue peculiar to many surface forms, especially in the tropics. Fishes are likely to have silvery sides, and dark bluish or olive backs. Lovely blues and violets characterize jellyfishes, Portuguese men-o'-war and numerous unrelated animals. Others are transparent, as the exquisitely delicate ctenophores or sea gooseberries, which move languidly beneath the surface and devour enormous numbers of tiny cod. The diaphanous young of multitudes of creatures dwell in the intermediate depths and approach the surface only at night. The leptocephalus larva of the common eel is transparent except for its tiny black eyes.

In the whole realm of marine life there are probably no more baffling problems than those connected with the migration of fishes. As is well known, salmon ascend rivers to spawn. The exact researches of C. H. Gilbert have demonstrated that the sock-eye salmon revisits not alone its natal river system, but the particular tributary of the river in which it was hatched. In some cases he has found that they return to the ancestral spawning bed. The young fish put to sea when upward of eighteen months old, and lead an oceanic existence for three or four years. On the return journey, after finding their river, what guides them so unerringly to their old home? Temperature has been invoked by Ward.[1] Let us examine the facts. As the salmon ascend the stream and reach the first spawning tributary all of them, though perhaps in varying degree dependent on their position in the stream, are exposed to the influences of the inflowing tributary as well as to the sum total of the environment at that point in the river. Yet some respond by turning into the tributary, while the rest go on: and those that enter the tributary are the ones that were spawned there. The same scene is enacted at the next spawning tributary and the next. Ordinarily, colder waters enter with the tributary, but if tempera-

[1] "Some of the factors controlling the migration and spawning of the Alaska red salmon," *Ecology*, II, 1921, 256.

ture is the guiding star of their existence, why do those who were not spawned in that particular affluent refuse to respond to the temperature stimulus? If their "homing instinct" dominates temperature stimulus in these cases, why infer that temperature is ever a controlling factor?

If we fall back upon memory, how shall we explain the dramatic odyssey of the river eel, traced by Johannes Schmidt of Copenhagen? In the autumn fully mature eels descend rivers and put out to sea on their first and only spawning migration. They swim prodigious distances. Those from the Baltic streams must work past Denmark and the British Isles. They then turn southward and disappear. It is now known, from a study of their queer ribbon-like larvae, that most of them cross the Atlantic to a region southwest of Bermuda, also frequented by the distinct American eel. The reason they vanish soon after leaving continental shores is because they spawn in the intermediate abysses, about three thousand feet down, and then die, as do the salmon after spawning. The transparent larvae, in size and shape much like a small willow leaf, dwell in this intermediate region, making nightly excursions to near the surface, where they associate with their American relatives, whose parents have made a somewhat shorter journey from the rivers of North America.

When the young become a little over an inch long, the two species separate. One starts for America, the other for Europe, to which the journey consumes about a year. First they grow to be from two to three inches long, but afterwards gradually shrink as they become slenderer until when near shore they are tiny eels. In the spring they ascend rivers, the females for the most part proceeding to headwaters, while the males remain near or in tide-water. Here they live for five or more years before starting on that strange journey into the mid-Atlantic abysses from which they never return. What guides the adults to the spawning places? Why do American and European larvae sort out, one turning to the left, the other to the right, with seemingly nothing to guide them through the vast dark spaces to their future home? We simply do not know. But of one thing we are certain: These and a multitude of similar problems will always give zest to the study of marine life and will free it from any risk of becoming monotonous.

RETAINING WALLS

By Dr. JACOB FELD

Something there is that doesn't love a wall,
That sends the frozen-ground-swell under it,
And spills the upper boulders in the sun,
And makes gaps even two can pass abreast.
—Robert Frost: "North of Boston."

THE search for this something is an old problem in engineering research, and after building walls for several thousand years, we are just about beginning to get an idea of what this "something" really is. Walls have had a habit of failing, refusing to stay where put, more so probably than any other type of structure. The ancient Babylonians tried to solve the problem by a law which fixed a penalty for constructing walls that would not stand:

Summa banum bitam ana awilum ibuus ma sibi irsu la-uste isbi ma igarum iktuup banum su-u ina kas pim b'ramanisu igarum su-ati udanna-an.
—From the Code of Hammurabi, 2200 B. C.

The Harper translation of the Code of Hammurabi reads:

If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen the wall at his own expense.

The Romans built many revetments, fortification walls for the protection of their camps. Some of these walls have withstood the ravages of the natural elements as well as the man-made agencies of destruction. But the walls are so heavy and over-safe that the cost of such construction at this time is prohibitive. The problem passed on to the French military engineers of the 17th and 18th centuries, and it was with them that the idea of an experimental study of the action of soils originated.

At first it was thought that soils should be classed as liquids; but they act in a somewhat different manner. While a liquid will transmit pressure in all directions undiminished and will always act perpendicular to the surface which retains it, it is known that a material like sand will not transmit pressure undiminished, and the effect is not perpendicular to the wall. This is the reason for the use of gravel or crushed rock as a shock absorber, as in railroad track ballast, floors carrying heavy or vibrating machines or trucking, etc.

Such materials, often classed as granular, have more recently

been considered as solids in a divided state. But the very idea of division prohibits this classification. The deformation of the solid state, in which matter has a constant shape and a constant volume, implies the property of elasticity. As a matter of fact, the criterion for the solid state is the obedience of Hooke's law, "Ut tensio sic vis", the deformation is directly proportional to the force acting. This law does not hold in granular materials for compressive forces, and such materials have practically no tensile strength.

It was to obtain a little more information about the action of soils, especially as applied to the design of retaining walls, that the University of Cincinnati built a large apparatus to test the lateral pressure of granular materials. The design was based upon the most successful apparatus of the past, that of Dr. Heinrich Mueller-Breslau of the Charlottenburg Laboratories in Germany. The Cincinnati apparatus is, however, much larger and simpler in construction, yet it is the most accurate device ever made for this purpose.

It consists of a large concrete box, five feet wide, nine feet long, six feet high in the front and twelve at the rear. The front side, five by six feet, is left open and a wooden wall fits into the opening; the wall is not connected rigidly to any support but rests on two large platform scales. There are three horizontal rods situated so that the wall bears against them if moved away from the bin, one at the top in the middle and the other two at the lower corners. When the earth is shovelled into the bin, it exerts a pressure against the wall. The vertical effect is measured directly on the two scales, the horizontal push is against the three horizontal struts which are connected to bell cranks, elbow shaped levers, which transmit the pressures vertically onto the other three scales. In this way the effect of the earth in both directions is measured directly by platform scales, the simplest device possible for reading pressures.

It would not do to allow the wall to move appreciable distances. For then the grains in the earth or sand behind the wall would have an opportunity to change their relative positions, thereby influencing the acting pressure. By careful control, readings were obtained while the wall was restrained from moving more than 1/8000 inch vertically and 1/16000 inch horizontally. Such small distances are, of course, not visible and not easy to measure directly. By the use of levers, including those inside the scales, the distances were magnified 800 times.

Some valuable results were obtained with this apparatus. Unlike fluids, it was found that the pressure of soils was always oblique to the wall. To absolutely determine this result, the tests were repeated with glass and sheet metal backings on the test-wall. The

inclination for each type was different but it was a constant in all the tests with the same wall. It was found that this constant was the coefficient of friction of the filling material on the wall.

This coefficient may be found from a very simple experiment If a bottomless box (a chalk box with the bottom removed was used) is filled with sand and weighed, then placed upon a horizontal sheet of glass and by means of a spring scale the force required to move the box is determined, the ratio of this force to the weight of the sand is the coefficient of friction between sand and glass. Likewise for other materials. To eliminate the contact between the sides of the wood box and the glass, the bottom ends of the sides are bevelled to an edge so that, practically, the only contact is between sand and glass. The results of the large experiments then indicate that the effect of settling as the earth is placed back of a wall is to bring into play the friction on the back of the wall. A curious result found was that the friction of sand on glass was greater than on sheet metal. The same conclusion was drawn by Mueller-Breslau in 1906.

To find out how great the force exerted by the earth is, the experiments show that the so-called theory of the "wedge of maximum pressure" very closely approximates the actual conditions. Earth in a natural condition will assume a fixed slope to the horizontal. This is characteristic of every soil and is noticeable in the slopes of hills and mountains as well as in the smaller piles of sand or sugar which are usually seen. If a wall is put up and a material shovelled behind it, that part of the fill above this plane of "natural slope" tends to slip down. Such slip is prevented by the action of the wall as well as the friction along the natural slope. The theory of the wedge of maximum pressure assumes that not all of this material acts against the wall, because of the friction on the natural slope, and determines what portion should act in order that the pressure against the wall be a maximum. This theory was first announced in 1773 by Coulomb who also made such wonderful contributions to the other sciences, chiefly electricity.

One of the new features studied in these experiments was the effect of age and temperature on soil fillings behind a wall. One test consisted of watching a fill of wet sand for eight days, taking readings of the pressure and temperature at all hours of the day and night. It was found that the pressure against a wall is a maximum directly after the fill is put into place. It remains at this value, sometimes increasing slightly, for a few hours, but within 24 hours, some internal settlement or binding has caused the pressure to drop by sometimes over ten per cent. of the original value. The pressure then increases again, varying with the temperature. Each day, the highest pressure occurred at about 2 P. M., the lowest at

A If a builder build a house for a man and do not make its construction firm and the house which he has built collapse and cause the death of the owner of the house – that builder shall be put to death

B If it cause the death of the son of the owner of the house – they shall put to death a son of that builder

C If it cause the death of a slave of the owner of the house – he shall give to the owner of the house a slave of equal value

D If it destroy property, he shall restore whatever it destroyed, and because he did not make the house which he built firm and it collapsed, he shall rebuild the house which collapsed at his own expense

E If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen the wall at his own expense

Translated by R F Harper
"Code of Hammurabi" p 83 - seq

Jacob Feld 1922

about 4 or 5 A. M. The amount of variation throughout the day decreased as the age of the fill increased; the curve showing the variation of pressure with age is very similar to the usual "damped vibration" curve, such as the vibration of a violin string or a spring

The usual trouble in walls is the effect of surcharge loads on top of the earth. To determine their effect, kegs of nails, weighing 100 pounds each, were placed at various points on top of the fill and the effect measured. Loads off the theoretical wedge of earth which will exert the maximum pressure seemed to have but little effect on the pressure, while loads near the wall increased the overturning effect considerably. Similar kegs of nails were rolled across the fill and showed an increase in pressure. The remarkable point was that, after the loads were removed, the pressure did not diminish immediately. Loading seems to compress the earth, which remains in this state for several days, before it comes back to its original state.

Working with soils is a very tedious but interesting study. Small apparatus is practically worthless, for earth is not uniform and large quantities must be used to obtain reliable results. This is one reason why the research in soils has lagged behind the advances in the other branches of applied science. The tests described here required shovelling about 300 tons of material by hand. Hand shovelling is much more easily controlled with consequent greater accuracy and safety of the apparatus. A complete report will be found in the Proceedings of the American Society of Civil Engineers, April, 1923.

It will take numerous hundred more tons of shovelling before we can completely answer the question in the same poem by Robert Frost:

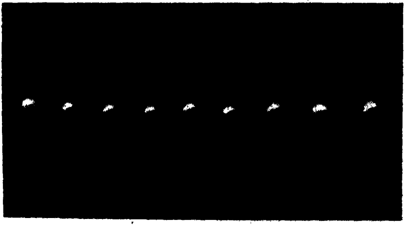
> Before I'd build a wall I'd ask to know
> What I was walling in or walling out,
> And to whom I was like to give offense.
> Something there is that doesn't love a wall,
> That wants it down.

THE CULTURE-PEARL FISHERY OF JAPAN

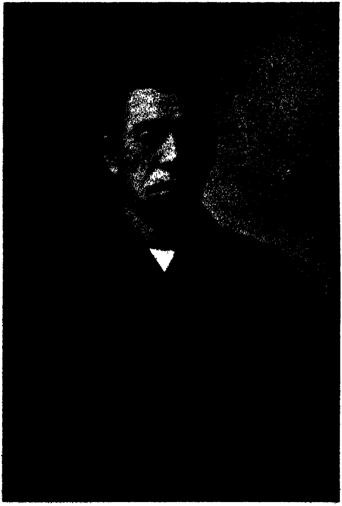
By Dr. DAVID STARR JORDAN
STANFORD UNIVERSITY

IN the south-middle part of the main island of Japan lies the large peninsula of Yamato, very mountainous and very picturesque, one of the early homes of the Yamato race, which, whatever its origin, now dominates Japan. On the east side of this area, stretching along the shore of the bay of Ise, lies the province of Ise, with the large seaport towns of Tsu and Yamada, the latter world-famous for its forest-embowered Shinto shrines, to which every pious Japanese who is not a Buddhist is supposed to make a pilgrimage every year. Just south of Ise lies the diminutive province of Shima, made up of delightful peninsulas, islands and intervening bays, suggesting a fragment of Greece but with very different human surroundings. Its chief town is the little fishing city of Toba, and twenty miles south of Toba is the unique Mikimoto Pearl Oyster farm.

The writer was in Yamada in November, 1922, in company of Senzi Yamamoto, lecturer on genetics in the Imperial University of Kyoto, who helped him to complete his large collection of Japanese fishes. While there we received an invitation from Kokichi Mikimoto to visit his pearl farm, his automobile being sent to meet us at Toba. We left Toba on one of the rare perfect days which come to Japan in November only and even then but seldom. The air was



MIKIMOTO'S CULTURE PEARLS
Taken from nine pearl oysters (slightly enlarged); November, 1922.



KOKICHI MIKIMOTO

free from mist and the outlines of the mountains of Yamato and of the barren sandstone islands of Shima were as clear cut as in the most atmospherically favored lands. After fifteen miles of narrow roads, across hill and valley, intersected by clear streams and forests ablaze with maples, the

Brown rocks weathering
'Neath their bamboo feathering

we reached Ago Bay.

Here Mikimoto met us with what was literally a steam tub, an open boat almost as wide as long with high bulwarks and no deck, its inside fitted with easy chairs. It was propelled by a little engine in front, adequate for the few miles of water between the shore and the sandstone island of Tatoku, the seat of Mikimoto's operations.

It has long been known that a species of Pearl Oyster (*Margaritifera martensi*) inhabits the waters of parts of Southern Japan. It is a small species, much less robust than the "Panama" oyster of the Gulf of California (*Margaritifera mazatlana*) and the west coast of Mexico.

The channels and inlets of Southern Shima (Shimei-ura) are unique in the clean sandstone bottom and in the entire absence of tributary fresh waters, while open to the warm wash of the Kuro Shiwo (Black Current), the "Gulf Stream," which sweeps northward from the Philippines and Formosa.

The Japanese people cared little for pearls (*shinju*) or other jewels, but they have found a ready foreign market for the relatively few gathered by the pearl-divers of Shima, who used to bring them in along with abalone (*awabi*) and agar-agar (*Gelidium*), a sea weed largely used in medicine.

In pearl fishing, Kokichi Mikimoto became early interested. He was born in Toba in 1858 and it is said that in his modest boyhood days he used to peddle about the town the Japanese equivalent to macaroni. It is well known that the pearl is secreted, layer by layer, from the mantle or soft envelope of the pearl oyster to cover a form of irritation, usually that of some parasitic worm, a fluke (Cestode) or the larva of a tapeworm. In the early nineties, Dr. Kokichi Mitsukuri, dean of the College of Science in the Imperial University of Tokyo, most distinguished of Japanese men of science, suggested to Mikimoto the possibility of producing pearls by artificial irritation. This idea was carried into practice by Professor Isao Iijima, and Mikimoto, aided by his clever son-in-law, Dr. Nishigawa, undertook in 1880 the bold plan of pearl-farming on a great scale, a large and costly venture demanding great initial faith, the first harvest being marketed eight years later.

PEARL DIVERS AT TATOKU ISLAND

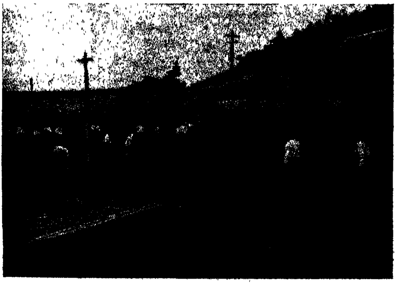
Leasing the picturesque island of Tatoku as a base of operations, he secured the rights to about fifty miles of the bays around it. A portion of this area is given to the spat or young oysters. Small stones are scattered over the bottom and to these the newly hatched fasten themselves by a byssus or set of threads. These are left to grow for about three years. They are then gathered and under the mantle of each one is introduced a small round fragment of oyster shell (mother of pearl). These are then transferred to the south side of Tatoku Island into water so deep (thirty to forty feet) as to prevent all danger of freezing. The animals are "planted" about a foot apart and held for some five years more, when they are brought up by the divers, nearly every one having then a pearl of some value, the market price of these "culture pearls" (*Yoshoku Shinju*, "pearls for foreign taste") ranging usually from $200 downward, according to their size, form and purity. As they are of exactly the same substance and color as the natural or "uncultured" pearl, there is no real reason why they should not have the same value. The culture pearl is formed about an irritating bit of mother-of-pearl; the other is the sarcophagus "of a worm untimely dead." Each sort has the same luster and sheen, a quality which cannot be imitated by any form of "paste" or artificial pearls. The chief drawback, a tendency to flatness on one side of the culture pearls, has been largely overcome.

The best methods of irritating the pearl oyster have been carefully studied, and patents of this process have been taken by Miki-

moto. Following his methods several other pearl farms have been established in similar waters elsewhere in Southern Japan. The output of the Mikimoto farm for 1921 amounted to about 1,200,000 yen ($600,000). The total yield from Japan now approaches $5,000,000 yearly.

The pearl divers (*ama*) at Tatoku form an interesting group. These are all young women from eighteen to thirty-five years of age, vigorous and muscular. It is said that the profession has become hereditary in the province of Shima. Women are preferred to men for this work, as it is claimed that they can stay under water longer (two to three minutes). Their husbands find employment in taking care of the shells and pearls and in other duties about the island. Mikimoto's divers wear cotton suits not unlike pajamas, white cotton caps, and a large water glass for better vision. Each one as she dives from the boat has with her a floating tub in which to deposit her clutch. In the interval between plunges the divers kept up a sharp whistling, a process which is said to give them lung-strength for their work.

The salt water tends to coarsen the skin and to redden the hair, but the women seemed unusually robust and in their way not unattractive Like all other Japanese, they are endlessly good natured, and when we left the island, after they were back in kimono and obi, they said *Sayonara* (good-bye) in the friendliest fashion, waving their handkerchiefs until we were out of sight. These women are in their way aristocrats among divers, unlike the red-skirted,

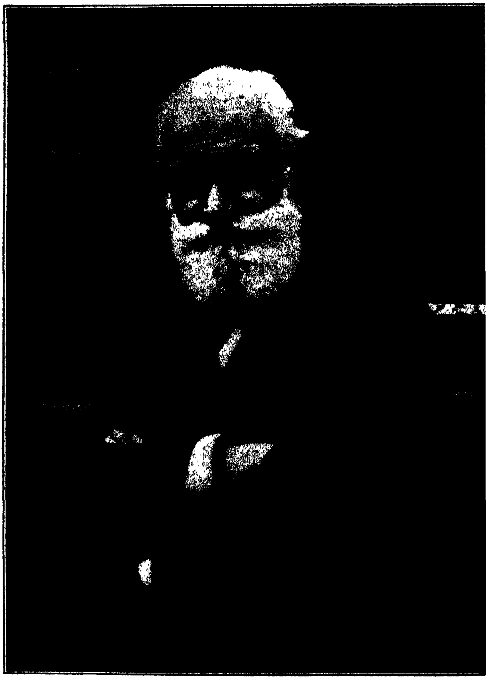


SORTING THE CULTURE PEARLS AT TATOKU ISLAND

naked-shouldered water-sprites who gather abalones (*Haliotis*), locally known as *awabi* and agar-agar (*Gelidium*) off Toba, Matsushima and many other places in Japan.

The rearing of pearl-oysters (*kaki*) is not without its difficulties. Star-fishes sometimes invade the beds, thrusting their protrusible stomachs into the opened shell and then digesting out the animal. Carnivorous sea-snails attack the oysters and boring worms and mollusks do their share of mischief. Sting-rays are often destructive as on ordinary oyster beds The growth of certain sea weeds sometimes chokes the young animal. Worst of all an invasion of a type of minute organisms from the Kuro Shiwo occurs at times. These creatures constitute the dreaded *Akashiwo* or red current, fatal to these mollusks.

The harvest season for pearls is in early December, but Mikimoto sent out for our edification nine of the divers, each one bringing in a pearl oyster. Opening these in his summer house on the hill, a pearl was found in each one. Two of the oysters were fried for my luncheon and in one of these (very delicious by the way) I found a minute natural pearl. Our visit ended, Mikimoto gave the whole pearl catch of the day as a present to Mrs. Jordan, a friendly souvenir of a delightful and instructive visit.



IVAN PETROVIC PAWLOW

The distinguished physiologist of the University of Petrograd. Photographed at Wood's Hole by Julian P. Scott, when Professor Pawlow lectured there at the beginning of July.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

COPPER IN COMMON LIFE

EVERYONE knows copper, however little he may know about it. The first object to attract his infant eye was very likely the brass knob of a bed or door. He early learned the monetary value of the metal by finding that it was legal tender for saccharine delights at the candy shop or slot machine.

So also in the childhood of the race was copper the first known of the useful metals. Some savage scientist, unknown to fame, picked up a piece of jagged red rock that seemed more serviceable as a knife than the familiar flake of flint. But when he tried to sharpen the edge with a stone hammer he found that instead of chipping off in little shell-shaped scales the strange material gave way beneath the hammer blows without breaking and so could be beaten into any desired form.

We may imagine the pride with which the pre-historic inventor exhibited his new-fangled knife or spear-head to his tribesmen, but we may also surmise that they laughed at him for carrying around such a queer contraption, and that when he demonstrated its superiority over flint he was robbed of his invention by some less original but stronger warrior. For we can not imagine that troglodyte society was so superior to ours that an inventor would meet any better fate than he does nowadays.

Comparatively few people know how beautiful copper is because comparatively few people have ever seen it. What most have seen is but the painted face of copper, the mask it puts on when exposed. To see the metal as it really is one must strip it of its concealing coat by heating it to redness in a glass tube through which hot hydrogen gas is streaming Then the copper is revealed as a shining silvery metal, delicately tinted with pink like the inner petals of a rose, less garish than gold, less steely than platinum

But draw the copper from the closed tube and let a breath of air strike it and instantly a blush spreads over its face, deepening to a red, as a baby's skin burns in the seaside sun. This soon darkens to a dull bronze, and further action of the air and moisture gives it a greenish or bluish tint. This fine patina is highly esteemed by artists and antiquarians on roofs and statues, but our municipal authorities call it "verdigris" and scratch it off occasionally with a sand-blast. They had better leave it on for both esthetic and economic reasons, for the bare metal can not stand exposure and no paint is more protective than this that is made by the very atmospheric agencies against which protection is sought. Copper coins and castings, coated with the patina, are preserved intact for thousands of years though buried in damp soil where iron implements would soon vanish in a heap of rust.

The readiness with which copper forms affinities with various elements gave it the name of "the meretricious metal," as the alchemists called it. But this very versatility has its value for human needs, for copper in combination assumes many beautiful and useful forms. The greens and

blues of malachite and azurite are gorgeous as any gems, yet they may be had in masses large enough to make tabletops and mantel-pieces. Glass and pottery get various tints from traces of copper, and "blue vitriol" is equally familiar to the electrician and the horticulturist.

Copper is a good mixer and enlarges its field of usefulness by alliances with other metals. Tin gives it the hardness of bronze. Zinc gives it the golden glitter of brass. With nickel and zinc it makes a passable silver. With aluminum, which man has lately learned to extract from common clay, it forms new and useful alloys. The noble metals, gold and silver, in their proudest capacity as coins and jewelry gain strength by alliance with the more plebeian copper.

Copper gets its name from the fairest of the goddesses who chose it as the metal of her mirror. This was, it must be confessed, "Hobson's choice," for Venus is older than she looks and when she rose from the sea, somewhere off the island of Cyprus, her first request was for a looking-glass that she might see for herself the reason for the admiration she perceived in all men's eyes. She was not content like Narcissus with the pallid reflection of a pool, which besides could not be carried around with her, so she sought for a suitable metal. There were only two known at the time, gold and copper. Gold she rejected; not, we must assume, on the ground of expense, for Venus has never lacked admirers eager to pay for her luxuries, but probably because gold cast a sallow tinge on her countenance while copper brightened the tint of her auburn locks and endowed her cheeks with a blush like that of modest maidens.

Anyhow, the handglass of the Cyprian Aphrodite became the symbol of her sex and is still to be found as such in our modern manuals of botany and zoology. The "cyprium" from the Cyprian isle became the "cuprum" of the Romans and the "copper" of the English, and the metal from which was fashioned the jewelry of goddesses and queens was made into pots and pans and the cheapest of coins. A copper button that was proudly worn by a Pharaoh of 4400 B. C. has been found in an Egyptian tomb but it is not nearly so elegant as the buttons that the elevator boy lavishly displays on his uniform.

"Not worth a copper" is the nadir of value yet copper is worth much to the world and never more than in this age of electricity.

THE LIONESS AND THE HARE

ONCE upon a time, many years ago, a hare boasted of her large family to a lioness. The lioness admitted her quantitative deficiency but added that her one offspring was a lion. It was a conclusive retort—at the time. The lioness had no need to be disquieted by the success of her rival in maternity; indeed, she could rejoice in it, for there was no danger that the hares, however numerous, would crowd out the lions; on the contrary, if there were more hares, there would be more lions and better fed.

Now, however, conditions have so changed that the reply of the lioness is no longer satisfactory. We have put a stop to killing as a factor in the struggle for existence. The lion has his claws trimmed and his jaws muzzled by law. The battle is not to the strong, but the race is to the swift-breeder. The lion and the hare are compelled to live peaceably together and are placed on an equality. Questions are decided by counting noses, not by matching muscles or weighing brains. There is no reason to think that the propaganda of Neo-Malthusianism will ever influence the hares,

nor that any legislative bonus will increase the size of leonine families. Consequently lions are becoming extinct and hares are multiplying all over the earth.

In its modern form, therefore, this fable teaches that the hares are bound to beat the lions in the long run, no matter how much bigger the latter may be or how much louder they can roar.

And having extracted this lesson of eugenics from the fable, drop it right here. A fable is a single-barreled weapon and if you attempt to get more than one shot out of it it is likely to explode, to the injury of the user. So I am not going to discuss whether the savage and predatory lion is a nobler beast than the meek and vegetarian hare and better fitted to populate the world. Still less am I going to identify with the lion and the hare any particular classes or races.

WHAT DID YOU SEE IN THE ECLIPSE?

An eclipse of the sun is one of the few scientific events in which everybody must take an interest. It absorbs the attention of the astronomers of the world, and it does not pass unnoticed by chick or child within the path of totality. It is not now viewed with alarm as in former ages nor held to presage the fall of kings, for both astrology and kings are now generally recognized as exploded fallacies. But an eclipse remains as awe-inspiring a spectacle as ever, and is more fascinating to watch than when it was shrouded with superstition.

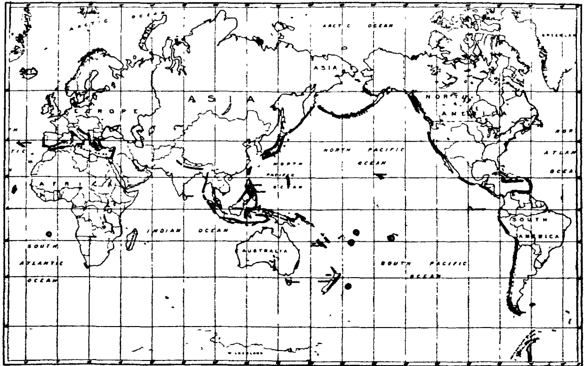
We are used to seeing total eclipses of the sun by the earth, for they occur to us every evening everywhere, but a man is rarely lucky if a total eclipse of the sun by the moon comes his way once in a lifetime. The eclipse of September 10 was total only for a strip of the southern coast of California, but the sun was seen as half or more obscured over the entire United States some time between the beginning of the eclipse at 11.15 A. M. in Washington state and its ending at 5.50 P. M. in Florida.

Since the moon has no atmosphere the edge of its shadow is sharply defined, and it can not "overcome us like a summer cloud without our special wonder." To those who are on a high mountain or in an airplane in the path of totality the advancing shadow seems to sweep over the landscape as a wall of darkness, advancing at the rate of a mile in two seconds.

Did you look for the mysterious "shadow bands" that flicker over white walls or other smooth surfaces a few minutes before and after the eclipse is total? They appeared as a swiftly moving series of wavy dark lines, an inch or more wide and a foot or less apart. How fast did they move? Faster than you could run?

Possibly you caught sight of "Baily's beads" named after the British astronomer who in the eclipse of May 15, 1835, observed that the last slender line of light broke up into a chain of dark beads just before the sun was covered by the moon's disk. What color was the last strip? Crimson, yellow or brick red? Bright red protuberances might have been discerned about the darkened disk; "a box of ebony garnished with rubies" somebody has called it. These are jets of incandescent hydrogen ejected from the sun, sometimes a hundred thousand miles into space.

When the sun was quite covered you may have seen the halo or corona which was the chief point of scientific interest in the eclipse. It varies greatly in size and appearance with the state of activity in the solar atmosphere at the time. Sometimes it resembles the cross of light that you



MAP OF THE WORLD ON MERCATOR'S PROJECTION

Showing the regions of the greatest earthquakes and volcanic activity, which are also the regions of greatest earthquake danger.

see about the moon as you look at it through a wire window screen. How far out did the streamers extend as compared with the diameter of the sun's disk? In what direction did they run? Were they symmetrically arranged about the sun or did they reach out farther on one side than the other? Could you draw a picture of the corona as you saw it to compare with the photographs taken by the big telescopes? Was it dark enough to see stars? How many?

But you may have found it more interesting to watch the earth than the sun. Even those at a distance from the region of totality could observe and photograph the curious crescent-shaped flecks of light that appeared in the shadows of trees. How dark did it get? Could you read? Tell time by your watch? Indoors or out? Did it get colder? What did the thermometer say about it? Did a wind start up? As the eclipse became total did the clouds seem to come closer and take on iridescent hues? How did the faces of your friends look?

Did you watch the dog and the cat? Did the birds become quiet and go to roost? Did any flowers close their petals or sensitive plants their leaves? They say that during a total eclipse grasshoppers take a nap while ants keep on working. This is what we should expect from their characters in the fable, but do they?

There was plenty to keep one busy during the two hours or so that the eclipse was on and especially during the two minutes or so that it was total.

THE GEOGRAPHY OF TOKYO

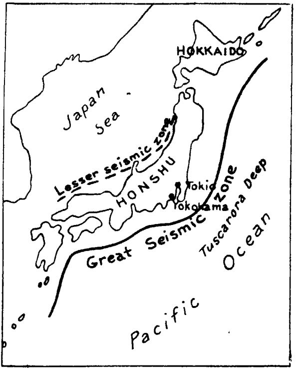
To get a mental picture of Tokyo one must hold clearly in mind that Japan's capital was not really a city but a collection of towns and villages, grown together, the National Geographic Society's news service writes from Washington. These settlements preserved their entity in the fifteen "wards" so frequently mentioned in recent dispatches.

In strolling through old Tokyo, and seeing the frail bamboo and cardboard houses, one could not help considering that the introduction of western buildings greatly enhanced the danger from earthquakes - a speculation now so sadly confirmed.

For the fragile houses might be burned and often were, but could not maim their occupants under piles of mortar and stone. Fireproof warehouses were provided for groups of such buildings and when the alarm of fire was sounded the occupants carried off their valuables to these storage places. A proverb had it "Fire is the blossom of Yedo"—using the older name of Tokyo which was abandoned when the Mikado took up his residence there in 1869.

Japan has had her troubles from volcanoes as well as from earthquakes. For reasons that geologists believe to be inherent in the very constitution of the globe, volcanoes have draped themselves in surprisingly regular festoons—like a chain of pearls caught up at intervals—down the whole Pacific coast of Asia. And of these crescent shaped strings of fire-mountains, the main island of Japan, Honshu, itself a crescent, forms the very center.

The northernmost of the volcanic crescents even touches America, since it is composed of the Aleutian Islands, stretching from Alaska to Kamchatka. The second festoon curves from Kamchatka through the Kurile Islands to northern Japan.



MAP OF JAPAN

Showing the zone in the deeps of the Pacific from which most of the great earthquakes emanate and a zone of lesser activity in the Japan Sea.

Then comes Honshu, the island on which Tokyo and Yokohama are situated. Those ill-fated cities lie at almost the extreme bulge of the central volcanic crescent where the island bends into the Pacific toward a very deep depression, extending perhaps 18,000 feet below sea-level. This great "trench" beside Honshu's foundation, may itself have placed the island in a rather weak structural position.

South of the central Honshu crescent there are two other well defined volcanic festoons, one through the Lu Chu Islands to Formosa; and another from Formosa through the Philippines and Borneo into the great volcanic complex of the East Indies

On Japan's main island, which has approximately the area of Great Britain, there are a dozen volcanoes that may be considered active and a greater number that are inactive. The closest and most important of the volcanoes near Tokyo are the famous and beautiful Fujiyama, sixty miles to the southwest, which has not erupted since 1707; and Asama, ninety miles to the northwest, which constantly sends up a thin wisp of smoke, and now and then breaks out into a vigorous eruption.

Tokyo has had three particular furies of her own to harry her over and over again, pestilence, fire and earthquake. From the close of the sixteenth century, when the old fishing village of Yedo blossomed into a city at the order of the ruling Shogun, to the present disaster, these three have from time to time taken heavy toll.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1923

"LOUIS AGASSIZ, TEACHER"[1]

By Dr. DAVID STARR JORDAN

STANFORD UNIVERSITY

I

IN a recent review, Dr Edwin E. Slosson suggested that some graduate student should take as his thesis "The genealogical tree of great American scientists" or "The contagion of ideas," using as an example the far-reaching influence of Agassiz But what of the forces that moulded Agassiz? In his case the contagion of ideas goes directly back to the great embryologist of Munich, Ignaz von Dollinger. To Cuvier and Humboldt, also, he gratefully acknowledged his profound indebtedness, but he once said to me:

> I lived for three years under Dr Dollinger's roof, and my scientific training goes back to him and to him alone. It was Dollinger who first taught me to trace the development of animals.

Of his own lodging in the scientist's home at the University of Munich he spoke as follows in one of his addresses.

> It was bedroom, library, drawingroom, study, fencing-room all in one; students and professors used to call it "The Little Academy."

In that "little academy" some of the most important discoveries of the time were made. There were first discussed the distribution of Baltic fishes, the anatomy of the lamprey and, most important (by Schimper and Braun), the law of phyllotaxy, "the marvellous rhythmical arrangement of the leaves of plants," as Agassiz described it.

In Europe, Agassiz was a student and investigator rather than a teacher. Yet, in his brief professorship at Neufchâtel, he showed the same tireless energy which built up the Museum of Comparative Zoology at Cambridge. With boundless enthusiasm he gathered

[1] Designation used by Agassiz, in his will This essay was read at the fiftieth anniversary of the school at Penikese, August 13, 1923.

about him a houseful of cooperating students, a hive of workers, sharing with them his scanty income and maintaining a publishing house with a steady output of useful works, the largest and most pretentious being his "Nomenclator Zoologicus." His monumental contributions came later, however. They deal on the one hand with the fossil fishes, on the other with the glacial system of the Alps and of Northern Europe.

Leaving Neufchâtel, he went to study at the Jardin des Plantes in Paris. Here he came under the influence of Cuvier, the great master of comparative anatomy, whose mission was to make the classification of animals not an arbitrary scheme of convenience but a reflex of their structure. Before Cuvier, taxonomy had little meaning. Each different kind, very uncritically described, was called a species and flung into a convenient genus, as into a pigeon-hole; that these adjustments correspond to essential realities of structure and of origin was scarcely apprehended. It was left to Darwin to lead systematists to realize that a permanent scheme is a map of relationships and that systematic zoology and botany rest finally on our knowledge or conception of genetic origins and connections. In large degree, Agassiz's attitude was a continuation of that of Cuvier, whose mantle was said to have fallen on him.

In the Jardin des Plantes, according to Theodore Lyman, one of his early students:

He worked for years, never knowing the value of silver except as it served to get his meals at some café of the students, or when very fortunate, to buy some scientific book second-hand from the open air stalls near the Institute.

His small handwriting, which seemed unnatural in so broad and impulsive a character, was a result of early necessity. On the backs of old letters and on odd scraps of paper he copied as closely as possible many volumes which he needed but could not buy.

Those little low rooms, five in all, in the old building at Paris, propped up at one end with timbers—they should be the mecca of scientific devotees! Perhaps every great zoologist of the past hundred years has sat in them and discussed the problems which are always inviting solution and are never solved. Cuvier, Humboldt, Johannes Müller, Valenciennes, Von Baer—they have all gone except the last, who lingers to remind us of the giants that once were.

Everywhere in these galleries and laboratories, it is the same. You are surrounded by the traditions of science. The spirits of great naturalists still haunt the corridors and speak through the specimens their hands have set in order.

It was in Paris, also, that Agassiz first met Humboldt. In an address at Boston he graciously describes his relation to the author of "Cosmos":

Humboldt's sympathy for all young students of nature was one of the noblest traits of his long life. It may truly be said that towards the close of his career there was hardly one prominent or aspiring young man in the world

who was not under some obligation to him. His sympathy touched not only the work of those in whom he was interested but extended also to their material welfare and embarrassments.

At that period (1831) I was twenty-four and he, sixty-two. I had recently taken my degree of Doctor of Medicine and was struggling not only for a scientific position but for means of existence also. He gave me permission to come as often as I pleased to his room, opening to me freely the inestimable advantages which intercourse with such a man gave a young investigator like myself. But he did far more than this. Occupied and surrounded as he was, he sought me out in my own lodging. The first visit he paid me at my narrow quarters in the Quartier Latin was characteristic of the man. After a cordial greeting he walked straight to what was then my library—a small bookshelf containing a few classics, the meanest editions bought for a trifle along the Quays, some works on philosophy and physics, his own views of nature, Aristotle's "Zoology," Linnaeus's "Systema Naturae," Cuvier's "Règne Animal," and quite a number of manuscript quartos, copies which, with the assistance of my brother, I had made of works I was too poor to buy, though they cost but a few francs a volume.

Most conspicuous of all were twelve of the new German cyclopedia presented to me by the publisher. I shall never forget, after his look of mingled interest and surprise at my little collection, his half-sarcastic question as he pounced on the great encyclopedia, "Was machen Sie denn mit dieser Eselsbrucke"? ("What are you doing with this Ass's Bridge"?)

It was, no doubt, apparent to him that I was not over familiar with the good things of this world, for I shortly received an invitation to meet him at six o'clock at the Palais Royal, whence he led me into one of those restaurants the tempting windows of which I had occasionally passed by.

When we were seated, he half laughingly, half inquiringly, asked me whether I would order the dinner. I declined the invitation, saying that we should fare better if he would take the trouble. And for three hours which passed like a dream I had him all to myself. How he examined me and how much I learned in that short time!

How to work, what to do, what to avoid, how to live, how to distribute my time, what methods of study to pursue—these were the things of which he talked to me on that delightful evening.

It was not enough for him to cheer and stimulate the student; he cared also to give a rare indulgence to a young man who could allow himself few luxuries.

In 1846, at the age of 39, Agassiz left Paris for America. "He came in a spirit of adventure and curiosity. He stayed because he loved a country where he could think and act as he pleased and where his ceaseless activity would be considered a high quality—a land where nature was rich, but tools and workmen few and traditions none." "It was the act of a man bold, restless and original. He was not spurred by failure, for his reputation had been already made" by his monographs on the glaciers and the fossil fishes, and he had been offered the directorship of the national museum at the Jardin des Plantes, than which no higher distinction could be granted by France.

His entrance into the faculty of Harvard College marked the

beginning of a new era in American education. He has been called our first university builder, because of his unprecedented emphasis on advanced and original work as factors in mental training. He laid great stress on the direct study of nature; to know something well is "the backbone of education." Science is built on induction; it is human experience tested and set in order. Hence arose his zeal for research, and his enthusiasm "set the heart of the youth in flame." A new force shattered the self-satisfied routine of Harvard!

Some of his associates took alarm at this; it was "making the college lop-sided," they thought. Even broad-minded Emerson suggested that something should be done to check the rush towards natural history Agassiz retorted that if the college were becoming one-sided, the remedy was not to cut off the vigorous growth, but to stimulate the rest. "I, for one," said he, "would be willing to run a race with any of my colleagues." At one time he declared, as his greatest achievement, that he had "taught men to think." A great teacher always leaves a great mark on every student with whom he comes in contact.

Agassiz was a born optimist; his strength lay largely in his realization of the value of the present moment. He was always ready to help and encourage—"the best friend that student ever had." A contagious enthusiasm surrounded him like an atmosphere. He was a living illustration of Thoreau's aphorism, "There is no hope for you unless the bit of sod under your feet is the sweetest to you in this world—in any world."

During this period he took a vigorous interest in the work of the lower schools. The science they taught was mostly of the routine order, "fourteen weeks" of memorizing in one subject after another. Whenever opportunity arose, he strenuously urged a better method. Speaking before teachers, he always displayed the actual material with which he had to deal. "There will never be good teaching in natural science," he said, "nor in anything else until similar methods are brought into use." He also insisted that a year or two in natural history, the study of things that are, would give the best kind of training for any sort of mental work. Referring to the prescribed "classical course," he used to say, "Harvard is a respectable high school where they teach the dregs of education."

Vivid accounts of his methods of dealing with individual students have been given by Professors Nathaniel S. Shaler, Addison E Verrill, Burt G. Wilder and especially by Samuel H. Scudder. All these are now brought together in a useful little book, "Louis Agassiz as a Teacher," by Professor Lane Cooper of Cornell.

It was an essential feature of Agassiz's training that he turned men from their chosen groups and gave them for inductive study something of which they knew nothing. They were thus thrown on their own resources to build from the bottom without the burden of bad habits or confusing recollections. Mr. Scudder, a student of butterflies, was set to work for a year on *Haemulon*, a genus of tropical fishes known as "Grunts" or "Roncadors." Shaler, a geologist, was given a series of flounders to compare and dissect, and Morse, an artist, found it his task to know the common clam. Before Hyatt and others were put boxes of mixed fish-bones to be sorted out and arranged. To me, a botanist especially interested in seaweeds, he gave charge of the schooner "Nina Aiken," with which I was to visit the pound nets (or stationary traps) on Martha's Vineyard to gather material for the Museum of Comparative Zoology. Here, then, I made my first acquaintance with marine fishes, finding them in bewildering variety and so full of interest that I have never turned back to the flowers I had formerly studied with eager zest.

In Agassiz's first class of advanced students at Harvard were William James, the philosopher, Joseph Le Conte, the geologist, and David A. Wells, the economist. Subsequent classes, including those present the first summer at Penikese, embraced nearly all the teachers of zoology of what was then the younger generation. No list is now available, but among those personally known to me I recall Nathaniel S. Shaler, Edward S. Morse, Alpheus Hyatt, Jeffries Wyman, Burt G. Wilder, Charles F. Hartt, Addison E. Verrill, Samuel H. Scudder, Frederick W. Putnam, Alpheus H. Packard, Edward A. Birge, Charles D. Walcott, Theodore Lyman, Alexander Agassiz, William Keith Brooks, Charles Sedgwick Minot, Charles O. Whitman, Samuel Garman, Walter Faxon, J. Walter Fewkes, W. O. Crosby, Frank H. Snow, Ernest Ingersoll, Lydia W. Shattuck, Austin C. Apgar and a number of other excellent teachers in normal schools and high schools. Nearly all here enumerated became professors in natural science, using Agassiz's methods, though not one of them adopting all his conclusions.

So far as I know, I am the youngest naturalist now living who ever came under Agassiz's direct teaching, but each of my seniors spread his ideals far and wide. Indeed, I can scarcely recall the name of a single active naturalist in America or in Japan (for Morse taught in the Imperial University of Tokyo, where Mitsukuri, Iijima, Ishikawa and Kishinouye were in his classes) who has not been a pupil of one of Agassiz's students. Thus, the teaching of zoology now rests in the hands of the master's intellectual grandchildren and great-grandchildren. This fact lends point to Slosson's phrase, "the contagion of ideas," and its cognate, the contagion of personality.

II

But in these later days the field of zoological study has broadened and extended into many narrow specialties. Its problems are no longer largely limited to accurate classification on the basis of comparative anatomy nor even embryology nor geologic succession. The theory of evolution has passed far beyond the hypothesis stage, and present activity centers largely about heredity and variation and the physical mechanism on which both depend. No greater advance has been made in biology than the discovery of the physical basis of heredity, the details of which lie beyond a possible guess by either Agassiz or Darwin, demanding a fine technique and powerful microscopes such as neither of them knew. But one unfortunate tendency of this erudite study of what I may call the Mendelian phyllotaxy of life is to turn the beginners from contact and towards theory. A new vocabulary has been introduced—this applicable not to things that are, but to semi-metaphysical conceptions regarding them.

Goethe warned us that "theory is gray, while the eternal tree of life is green." Yet from green to gray, elementary instruction in America is now rapidly turning back. As the old "Fourteen Weeks" series served up the dry bones of obsolete classification, so the new biology brings the beginning student in face of inchoate conceptions, yet to be hardened into science, and in no way inspiring as an outlook on nature. We are, therefore, suffering from the "dry rot of academic biology," so vigorously portrayed by Professor William M. Wheeler. The teacher who roamed the fields with his flock and

> Wandered away and away
> With Nature the dear old nurse,
> Who sang to him night and day
> The songs of the Universe

is giving place to the closet and greenhouse investigator who deals with names of conceptions and tendencies as his predecessors did with species and genera.

To the Darwinian theory of evolution by natural selection Agassiz was persistently opposed. Essentially an idealist, he regarded all his own investigations not as studies of animals and plants as such, but as glimpses into the divine plans of which their structures are the expression. "That earthly form is the cover of spirit was to him a truth at once fundamental and self-evident." To his mind, also, divine ideas were especially embodied in animal life, the species being the "thought unit." The marvel of structural affinity—unity of plan—in creatures of widely diverse habits and outward appearance he took to be simply a result of the association

of ideas in the divine mind. To Darwin, on the other hand, those relations illustrated the tie of a common heredity acting under diverse conditions of environment.

But in a manner equally idealistic, it may be urged that if a species or line of heredity be actually changed by the obstacles that modify or split it up in its course, that fact may equally represent a divine thought. The problem before us is to find out the truth. Very few scientific men can conceive of the universe as undirected by some adequate and mighty intelligence, and certainly the evolutionist has a vastly more widened view of divinity than is possible to one to whom "the God of Things That Are" has never been revealed.

Yet Agassiz had no sympathy with the prejudices exploited by weak and foolish men in opposition to Darwin's views. He believed in the absolute freedom of science, and that no authority whatever can answer beforehand the questions we endeavor to solve—an attitude strikingly evidenced by the fact that every one especially trained by him afterward joined the ranks of the evolutionists. For he taught us to think for ourselves, not merely to follow him. Thus, though I accepted his philosophy regarding the origin and permanence of species when I began serious studies in zoology, as my work went on their *impermanence* impressed me more and more strongly. Gradually I found it impossible to believe that the different kinds of animals and plants had been separately created in their present forms. Nevertheless, while I paid tribute to Darwin's marvelous insight, I was finally converted not by his argument, but rather by the special facts unrolling themselves before my own eyes, the rational meaning of which he had plainly indicated. I sometimes said that I went over to the evolutionists with the grace of a cat the boy "leads" by its tail across the carpet!

All of Agassiz's students passed through a similar experience, and most of them came to recognize that in the production of every species at least four elements were involved—these being the resident or internal factors of heredity and variation, and the external or environmental ones of selection and segregation.

Referring to his work on fossil fishes in the early forties, Agassiz once told me, "At that time I was on the verge of anticipating Darwinism, but I found that the highest fishes were those that came first." That is, the sharks, the most primitive in some respects, had the largest brains, the most specialized teeth and muscular system, and judging from the nervous system alone should be regarded as the highest of fishes. But he had fallen into the error of supposing that evolutionary divergence could be measured in terms of progress. Sharks in most regards are primitive as compared with the

welter of bony fishes that followed them. The latter are more distinctly "fish-like," with an enormous variety of specializations, fitting them for their diverse forms of life. As with the sharks their transformations lie outside the line of the supposed ancestry of higher forms. Natural selection while bringing about "progress" in certain lines—or increased specialization through more varied relation to environment—by no means involves universal or even general progress. It leads to varied fitness to actual conditions. Natural selection preserves as ancestors those who run the actual gauntlet of life, and retrogression is as evident a factor in evolution as progress.

Moreover, it is not from the most specialized or fish-like fishes that the higher forms seem to have descended. The supposed ancestors of amphibians and reptiles are the nearly extinct Dipnoans, by no means the highest of fishes, but the most reptilian, and the only group from which higher vertebrates could have sprung.

III

The last and most picturesque of Agassiz's efforts was that which brings you together to-day, and it is a deep disappointment that I can not be present to pay my tribute in person to the greatest teacher I have known.

But in "The Days of a Man" (and elsewhere) I have given my account of Penikese. Its most memorable incident, one that will bear repetition, was recorded by Whittier in a beautiful poem. On the second morning, Agassiz rose from the breakfast table and spoke of his purpose in calling us together. The swallows flew in and out of the building in the soft June air. Some of them grazed his shoulder as he dwelt with intense earnestness on the needs of the people for truer education—needs that could be met by the training and consecration of devoted teachers. This was to him no ordinary school, he said, still less a mere summer's outing, but a missionary work of the highest importance.

A deep religious feeling permeated his whole discourse, for in each natural object he saw "a thought of God" which the student may search out and think over again. But no reporter took down his words, and no one could call back the charm of his manner or the impressiveness of his zeal. At the end he said, with a somewhat foreign phrasing, "I would not have any one to pray *for* me now," adding, when he realized our failure to grasp his meaning, that each would "frame his own prayer in silence."

> Even the careless heart was moved,[2]
> And the doubting gave assent
> With a gesture reverent
> To the Master well beloved.

[2] From "The Prayer of Agassiz," by J. G. Whittier.

As thin mists are glorified
By the light they can not hide,
All who gazed upon him saw,
Through its veil of tender awe,

How his face was still uplit
By the old sweet look of it,
Hopeful, trusting, full of cheer
And the love that casts out fear.

Two or three minor incidents described in my notes may be worth recalling. One evening we organized the Agassiz Natural History Society. Agassiz himself attended the first meeting, which in true American fashion was filled with discussions of constitutions and by-laws, constitutional amendments and election of officers. As he sat through our proceedings, he grew more and more uneasy; the business of a Natural History Society, he felt, was natural history, not constitution-making. So he explained how he had helped launch the great French Association for the Advancement of Science without a constitution or elected officers. The members having come together quietly, the youngest of all, without previous agreement, walked up, took the chair and called the meeting to order. "That impudent young rascal was I," said he, laughingly.

Another time Bicknell brought out his new stereopticon, and images of minute life, little jellyfishes, crustaceans and sea-worms were thrown upon the screen. The shapes and antics of some of these, immensely magnified, were very funny. Wishing to point out a notable feature—that is, the circulation of the blood corpuscles in the veins of a tadpole's tail—Agassiz approached the screen and in so doing stepped into the beam of light, when instantly his silhouette was cast upon the broad white surface with startling effect.

"It seemed to shadow forth," said Garman, "that distant day when future students of nature, looking back, shall see the figure of Louis Agassiz standing alone and majestic against an unoccupied background of American science."

One morning I heard Agassiz calling: "Mr. Jordan, Mr. Jordan, will you come and look at this!" It was a patch of grass thickly studded with mushrooms which had developed over night. "How did this happen?" he asked.

Looking about I found a place to the windward where the turf had been dug up. Apparently, therefore, loose dirt blown by the wind had borne and deposited many mushroom spores amid the grass. This conclusion we verified by discovering another excavation with its corresponding patch of fungi. I then explored the whole island, finding a mere half-dozen scattered individuals. It

thus seemed certain that spores could escape in abundance only by a fresh breaking of the turf.

The last letter I received from Agassiz (November, 1873) was an appeal to study the development of the eggs of the Gar Pike (*Lepidosteus*) abundant in rivers of Wisconsin, where I was teaching. *Lepidosteus* was of particular interest to him; at Penikese he had told me with zest how Cuvier showed him a precious specimen of this creature of reptilian affinity strongly resembling the extinct bony-scaled ganoids on which he himself was working. Moved by the interesting possibilities, Cuvier then gave him two scales for microscopic examination, and to Agassiz's delight he found these—diamond-shaped and enamelled—to be formed exactly like those of some of his fossils.

Agassiz's talks at Penikese covered a wide range of subjects—the European naturalists, the history of geology, the glacial system, methods of teaching. From my notebooks I have culled a few of his sayings, mostly unpublished, just as I wrote them down:

Never be afraid to say "I do not know."

Strive to interpret what really exists.

I feel more vexed at impropriety in a scientific laboratory than in a church. The study of nature is intercourse with the Highest Mind. You should never trifle with Nature. At the lowest, her works are the works of the highest powers, the highest something in the universe in whatever way we look at it.

I have been criticised in Europe as one who derives his scientific ideas from the church. I have been regarded in America as an infidel, because I will not be dictated to. I will not suffer my church-going friends to pat me on the head.

Have with traditional belief and dogmatic science nothing to do. Scrape it off. If we are weak let us humbly fall back for support on tradition and belief. If we are strong let us see what there is outside of these.

Never try to teach what you yourself do not know, and know well. If your school board insists on your teaching anything and everything, decline firmly to do it. It is an imposition alike on pupils and teacher to teach that which he does not know. Those teachers who are strong enough should squarely refuse to do such work. This much-needed reform is already beginning in our colleges, and I hope it will continue. It is a relic of medieval times, this idea of "professing" everything. When teachers begin to decline work which they can not do well, improvements begin to come in. If one will be a successful teacher, he must firmly refuse work which he can not do successfully.

It is a false idea to suppose that everybody is competent to learn or to teach everything. Would our great artists have succeeded equally well in Greek or calculus? A smattering of everything is worth little. It is a fallacy to suppose that an encyclopedic knowledge is desirable. The mind is made strong, not through much learning, but by the thorough possession of something.

Lay aside all conceit. Learn to read the book of nature for yourself. Those who have succeeded best have followed for years some slim thread which has once in a while broadened out and disclosed some treasure worth a life-long search.

A man can not be a professor of zoology on one day, and of chemistry on the next, and do good work in both. As in a concert all are musicians—one plays one instrument, and one another, but none all in perfection.

You can not do without one specialty; you must have some base-line to measure the work and attainments of others. For a general view of the subject, study the history of the sciences. Broad knowledge of all nature has been the possession of no naturalist except Humboldt, and general relations constituted his specialty.

Select such subjects that your pupils can not walk without seeing them. Train your pupils to be observers, and have them provided with the specimens about which you speak. If you can find nothing better, take a house-fly or a cricket, and let each hold a specimen and examine it as you talk.

In 1847 I gave an address at Newton, Massachusetts, before a Teachers' Institute conducted by Horace Mann. My subject was grasshoppers. I passed around a large jar of these insects, and made every teacher take one and hold it while I was speaking. If any one dropped the insect, I stopped till he picked it up. This was at that time a great innovation and excited much laughter and derision. There can be no true progress in the teaching of natural science until such methods become general.

There is no part of the country where, in the summer, you can not get a sufficient supply of the best specimens. Take your text from the brooks, not from the book-sellers. It is better to have a few forms well known than to teach a little about many hundred species. Better a dozen specimens thoroughly studied as the result of the first year's work than to have two thousand dollars' worth of shells and corals bought from a curiosity shop The dozen animals would be your own.

Teach your pupils to bring in their specimens themselves, and above all teach them how to handle them. The earlier this training is begun the better. There is not one person in fifty who knows how to handle a valuable specimen without injuring it, and not one in ten who will submit to being taught.

Talk about your specimens and try to make the pupils observe the most striking and telling features. When you collect a specimen, be sure and find out what it is, or if you have not the means at hand, take such notes as will help you to find its name when you have opportunity. Better let a specimen go without a name than to give it a wrong one.

There should be a little museum in every school-room; a half-dozen Radiates, a few shells, a hundred insects and a few fish, reptiles, birds and mammals would be sufficient to teach well. De Candolle, the great botanist, once said that he could teach all he knew about botany with a dozen plants.

If you study nature in books, when you go out-of-doors you can not find her.

The book of nature is always open. All that I can write or say shall be to make them study that book and not pin their faith to any other.

This is the charm of study from Nature herself; she brings us back to absolute truth whenever we wander.

THE WORLD AND ART OF THE ANCIENT CAVE MEN

By Professor HAROLD O. WHITNALL

COLGATE UNIVERSITY

THE world is much interested in the wondrous works of art that have been found in the tomb of Egypt's Pharaoh, Tut-ankh-Amen. Millions have read of the lavishness of the display, and its superb artistry has sent thrills through all lovers of the beautiful.

Such a discovery reacts in many ways on many minds. Some think of it only in pounds sterling or the American dollar. Those of a more artistic temperament or of finer sensibilities revel in the beauty of design and marvelous workmanship. The very antiquity of the tomb and its contents appeals most strongly to some, while others are thrown into a philosophical mood and exclaim with the preacher: "Vanity of vanities, all is vanity."

In the light of modern science Tut-ankh-Amen is but a man of yesterday and the art that surrounded him is one that had a very remote background. Man's antiquity is great, far exceeding the views that were held fifty years ago. Then, the problem of the occupancy of the earth by man was debated in thousands of years, while now it is a question of how many hundreds of thousands of years have passed since his advent.

The very ancient race that is our especial concern, a race possessing an unusually well-developed artistic sense, is known as the Crô-Magnon. It takes its name from a skeleton discovered many years ago in a cave in the valley of the Vézère, a tributary of the Dordogne in France. The descriptive term "very ancient" must not lead us to expect that our kith to be described are representatives of earliest man. It is generally agreed that Crô-Magnon tribes lived in Europe in late Paleolithic time, a period estimated to be from 20,000 to 25,000 years ago, three or four times as ancient as the Egyptians or Babylonians of the dawn of history, but several hundreds of thousands of years nearer to us than our primordial ancestors.

Europe was inhabited long before the coming of the Crô-Magnons by several different human races. Indeed, if the estimates of geologists are correct and the geological positions of these pre-Crô-Magnon remains have been rightly determined, man lived in Europe nearly a half million years ago. Hence the Crô-Magnons were comparatively recent migrants to the soil of Europe.

They were the artists *par excellence* of prehistoric time. Their mural paintings and parietal engravings that embellish scores of cavern walls in southwestern Europe are among the wonders of the world. To understand this art and fully to appreciate it, it is necessary to describe Crô-Magnon men, their habits, habitats and the scenes on which they looked.

Their physical type was superb. They were a tall race, standing well over six feet. The aboriginal races of Europe must have considered these immigrants as giants, even as the children of Israel thought of the sons of Anak. Besides their height, their broad shoulders, deep chests, slender, long and muscular limbs, with noble head well balanced on stocky but not bull-like neck, gave them a most stately bearing. The face approached the Caucasian type, although the projecting upper teeth and the prominent cheek bones spoiled what we would call "their good looks." Their physique, their cranial capacity and cast of countenance as restored through a study of their skeletal remains, compel us to regard them as one of the finest types that the world has ever seen. This estimate is augmented by the art they have left. Because of its great antiquity and the difficulties that environed the artists in its execution Crô-Magnon art is one of the most marvelous manifestations of man's artistic sense that has been found.

Thanks to the indefatigable labors of a small group of European scientists, who have slowly and carefully gathered scattered bits of evidence of the times in which Crô-Magnon man lived and who have patiently pieced together these bits of testimony, it is possible to build from them a mosaic, which, although containing gaps and breaks, here and there, is in the main a true picture of those remote days.

The Europe of that time presented a very different aspect from that of to-day. When the Crô-Magnon artists were drawing and painting pictures on stony walls in the gloomy recesses of caverns and Crô-Magnon hunters were stalking their quarry, Scandinavia was covered with an ice sheet which extended southward over the Baltic depression and rested its icy feet on the lowlands of northern Europe; the Alpine glaciers were much more extended than now and, from the high Pyrenees, ice-tongues crept slowly down towards the plains. In southern France, which seems to have been the center of Crô-Magnon culture, the air was chilled by the icy breath of the frozen north, while the less extensive ice areas to the east and south contributed no small amount of cold winds. The effect of such a bleak climate, with seasons of nipping chills, compelled men to leave open camps and to take refuge in the shelter of overhanging ledges or in the more protected caverns. Thus it was that Crô-

Magnon man passed a great part of his existence as a troglodyte.

Because of certain popular fallacies that concern the life of ancient man the temptation comes to parenthesize a paragraph and state that caves were not the first dwelling-places of mankind. Earliest men were children of the open spaces, dwelling along river banks or in park-lands, and it was only when compelled by adverse climates that they entered caves which afforded immunity from the raw winds and freezing cold. Again there is a current misconception that the men living during the glacial periods were dwellers near or even on the ice itself. Kipling is guilty of this fallacy when he writes of Ung, the Maker of Pictures:

> Straight on that glittering ice-field, by the caves of the lost Dordogne,
> Ung, a maker of pictures, fell to his scribbling on bone.

Now the fact of the matter is that the inhabitants of the Dordogne caves were 600 miles from the great Scandinavian ice-sheet; 200 miles from the Alpine cap, and at least 150 miles north of the small glaciers that lay in the higher valleys of the Pyrenees. It is probable that the bulk of the population had never seen ice-fields, although it is quite possible that legends were common of the great hard white ocean that lay on the confines of their world. The effect of the extensive frozen solitudes was keenly felt, but the cause was unseen and unknown.

Finally, it must be understood that the climates of the region in which these ancient artists lived were not uniform. Throughout the thousands of years of Crô-Magnon domination not only seasonable climates prevailed, but secular changes were also in process. The great climatic pendulum swung back and forth through the millenniums not with a steady movement but with periodic inequality. Furthermore, the arc through which it passed was short; never did the mean temperature rise to the present warmth of the region nor did it sink to arctic cold.

The fluctuations, however, were sufficient to permit at least three types of geographical features with their accompanying animal life. It is of importance to understand these climatic stages, for they, of course, dictated the fauna of those times. The knowledge of the mammalian life that was associated with Crô-Magnon man throws much light upon his own life and habits. Primarily, he was a hunter and his very existence depended upon the chase. Again, a knowledge of the animals gives testimony as to the vegetation and its distribution. Thus acquaintance with the climate, animals and plants enables one to have a vivid picture of those far-off days.

The culmination of Crô-Magnon art appears in the engravings

and monochromes and polychromes which were painted during the closing stages of the Crô-Magnon period. For thousands of years previously these savages had been engravers and sculptors both in the round and in bas-relief work; but most of their work had been done on portable objects as bone, ivory, horn and pieces of stone. It seems, therefore, that painting, which many art critics maintain is the apogee of all art, developed as a natural sequence in a race that was peculiarly sensitive to the artistic impulse. The high tide of art came in the final cultural phase of the race. This stage is known among prehistoric archeologists as the Magdalenian, so called from the type station, the cave of La Madeleine, on the Vézère. It is in the parietal engraving and paintings of these times that our chief interest lies.

This Magdalenian phase had three types of climate. Ushered in by a severe, cold, moist climate, tundra conditions were widespread over Europe, and the reindeer, mammoth, woolly rhinoceros and musk-ox grazed and browsed over a wide territory. So intense was the cold in southwestern Europe that even the musk-ox, that shaggy beast of the snow-fields, wandered as far south as the Pyrenees.

The climatic pendulum swung again. It still remained cold, but less moisture was in the air. Strong dry winds swept over the land, bringing clouds of dust which settled as a great blanket and remains even now as a geologic reminder of those great dust blizzards. This semi-aridity considerably diminished and changed the food supply of the animals. The dwarfed but widespread vegetation of the tundra wastes could not maintain its foothold generally; only along the margins of lakes and rivers and depressed swampy places did it persist. Great areas took on the character of cold steppelands. On such plains and hills the vegetation of spring and early summer soon became parched and offered but a precarious pasturage to grazing animals. The only animals that could survive in such regions were those that could exist on scant vegetation and that were fleet of foot. Representatives of such animals were the saiga antelope and a horse closely allied to the wild desert horse of Asia.

These and smaller mammals became quite abundant in western Europe during this period, and their bones are mingled with those of the tundra animals on many a charred hearthstone of Magdalenian time. For, although the semi-aridity must have driven out a large number of the tundra forms, a great proportion of them found sustenance along the grassy margins of the waterways and other favored spots.

The last stage of Magdalenian times was characterized by a moist and continually moderating climate. The steppe fauna dis-

appeared early and was followed by the gradual withdrawal, towards the ever-retreating ice front, of the tundra animals. Slowly, great forests, park-lands and meadows developed over Europe, and with them came the life of woodlands and succulent meadows. Typical of the meadow animals were the bison and wild cattle, while the forests became stocked with red-deer, stag, moose, wild boars and other denizens of the woods.

Such were the types of climate during the centuries in which the Magdalenian men of the Crô-Magnon race made their pictures on the walls of dark caverns. As we try to reconstruct the scenes on which the eyes of these ancient people rested we must be careful not to let the term tundra create an image of the illimitable leagues of the moss- and lichen-covered plains of northern Canada. Nor should the name steppe merely call to mind the great monotonous plains of southeastern Europe or northern Asia. For both these type regions suggest thousands of leagues of level stretches, broken only by gentle ridges rolled on one another in monotonous torpor.

Tundra and steppe conditions were present but on a much smaller scale. Southwestern Europe was, as regards the general features of the topography, the same then as now. The Garonne and the Dordogne, of France, and the Tagus, Ebro and Douro, of Spain, flowed as they do now through rocky gorges in their upper reaches and meandered across wider valleys as they approached the sea. Minor changes have of course come; most of the streams have deepened their valleys somewhat; many of the rocky ridges have been softened, and the hand of modern man has here and there produced considerable change. On the whole the contour of the land is not so different that it could not be recognized by those ancient inhabitants could they but see it. Climate does not always produce profound changes of the form of the earth but clothes it in varied costumes.

Nor was the sequence of the seasons different. Spring, summer, autumn and winter came to those ancient hunters as they come to the present peasants of the valleys and hills. In summer it was a land of sound, birds sang, insects hummed and the croaks of the amphibians rose from the marshes. Streams babbled and splashed their way to the sea and the summer winds produced the world-old whispers of the leaves. In winter it was a land of silence, broken only by booms from ice cracks, the crunching herds of winter animals on the crusty snow and the weird cries of winter birds.

In such a familiar world lived our ancient race, familiar and yet not altogether so, for of his animal associates few species have survived Types of many of them still persist, but some have vanished from the earth forever. Many of them were vital to the needs

of these men, for they supplied them food and clothes and bone implements. They were also the models of the artists, for the Crô-Magnon engraving and painting was confined almost exclusively to animal types.

We have glimpsed his hunting grounds; let us look at his habitations. Magdalenian man roamed over a large territory. So far, evidence of his presence has been found in Spain, France, Belgium, Germany, Switzerland, pre-war Austria and perhaps England. Although no proven Magdalenian stations have been found in England, there is no good reason why they should not be discovered there, for there was a land communication between France and England at the beginning of Magdalenian time. Whether this persisted throughout the entire time phase is not yet proven.

France was the center of Crô-Magnon population, and it was there and in the adjoining Pyrenees of Spain that his art rose to its highest expression. There are two regions, both in southern France, that were apparently highly favorable to the life of the Crô-Magnon Magdalenians. One was not far from the present Spanish frontier, along the head waters of the Garonne and its tributaries; the other was in Dordogne, along, or near, the valley of the Vézère, near its point of juncture with the Dordogne in a locality which takes its name from Les Eyzies. In the Les Eyzies district at least twenty caves and shelters have been found that contain Paleolithic remains, and in many of these mural paintings and parietal engraving occur.

There were many things that caused the Dordogne and adjoining regions to be favored by these ancient hunting tribes. Perhaps the most potent influence was the climate. It was not an ideal one, that is, not one that primitive man would have deliberately chosen; yet its very coldness was, had he but realized it, the spur that drove him on to better things. "Progress, adjust and adapt, or be destroyed" was the challenge that the cold long winters and chilling blasts brought to the European savage. He met that challenge and moved onward mentally and spiritually. It has always been thus. Man has met the bludgeon blows and rapier thrusts of nature and in so doing has learned to a great extent how to parry and overcome. He is "nature's insurgent son"; it is only where nature is kind that man remains nature's child.

Another feature of the environment that gave strength and well-being to the Dordogne tribes was the varied and abundant game, especially the large quadrupeds whose pictures adorn so many cavern walls. To those meat-eating savages these animals were the "staff of life"; without them they would have perished or else eked out a miserable existence from wild fruit, roots and an occasional

meal of fish. Then again the use of the animals' skins played a large part in their lives, enabling them to withstand the rigors of long and often severe winters.

But even with the abundant food supply and its important by-product of clothing it is difficult to imagine the population existing without shelters to shield them from the icy blasts of winter. They might have struggled through the cold seasons by living in skin tents as the Indians of northern Canada do, but such insufficient shelter would have lowered the vitality of the race and impoverished their mentality to such an extent that they would have degenerated, as the Terra del Fuegians have, to a state where life is only food and sleep and the instinctive rearing of children. This degeneracy they escaped because the geological forces of the past had grooved the hills with rock shelters and honeycombed the cliffs and rocky hillsides with caves. Thus, all things considered, it was a congenial region, furnishing plenty of food and clothing and homes that answered to their every need.

In all the Dordogne region the lower valley of the Vézère was best fitted for the dwelling-place of these savage troglodytes. In this region the Vézère flows through an old incised meander carved throughout the ages in limestone rocks. It is an extremely picturesque region. The river winds in long stately loops through a valley in which lie level and fertile meadows. On each side rise the limestone cliffs, sometimes abruptly for many feet. At other places their sheer sides are notched with broad ledges. Here and there the ledges extend inward and are overhung with massive rocks. These lateral flutings into the sides of the cliffs are the rock shelters, or, as the French called them, the *abris*. These shelters may be only overhanging cliffs, or they may extend inward and form grottoes. Occasionally they may be entrances to extensive caves. From the evidence at hand it seems probable that the shelters and the grottoes were the real homes and that the caves were only entered by the artist guild.

The cliffs are very striking features of the landscape, for their steep sides prevent the growth of all but the scantiest vegetation. Here and there a ledge, on which the talus material lies thick, offers a foothold for clumps of trees. The summits of the cliffs are well wooded. The picture that is presented in the summer time is most charming. The level valley with its fields of varied green tints, with the clear, strong, yet quiet river forms the foreground. From the outer bends in the river rise the light-colored rock walls, their barren sides colored here and there with hues of jade and emerald, their summits clothed with deep green woods.

Let the fairy godmother of time wave her wand over the region

and bring back scenes long gone by. Tundra conditions prevail. The general topography is the same, the river flats are ablaze with brilliant flowers growing in the scrubby vegetation of the hot but short summer. Herds of reindeer dot the plain. At times an ibex or chamois, driven from alpine solitudes by the all-embracing ice-sheet, walks with sure step along the rocky ledges. A half dozen stalwart savages climb fleet-footed up to a shelter under an over-hanging rock and with much gesticulation tell the group that receives them of herds of mammoth they have seen to the west. The hunters arm themselves with crude stone weapons and arrows and depart to capture, by direct attack or by pitfall, one of those great quadrupeds. Their hunt is highly successful, for they not only kill a mammoth but drive a woolly rhinoceros into mucky ground lying along the margin of the river and kill it while it struggles helplessly.

The magic wand of time is waved again. This time steppe conditions occur. It is late summer; the valley is bare of grass save along the river margins. There, nervously grazing, raising their heads constantly to "get the wind," were small groups of horses and slim-limbed antelopes. The Crô-Magnons look down upon them from their rocky ledges and whisper plans of surprising them, for these were the most difficult animals to hunt that the tribes knew.

Once more the wand describes a circle. Again it is summer, and the landscape presents almost the same view as now. The river flats are green and the cliffs shine white in the warm sunlight. The bare rocks are ribboned and crowned with green. Far down the valley the meadow is broken by woodlands. In the forests of the plains and hills live the red-deer, moose, stag and wild boar. At night the sleepers on the cliffs are awakened by the howl of wolves, and cave-bears blundering on the ledge above loose a shower of stones which rattle down the cliffs. The Magdalenians arise from their skin-blankets and heap on some more firewood, for they know that the "red-god" is feared by these wild prowlers of the night.

Since 1828 when Tournal demonstrated the association of man with extinct animals of the glacial period in the grotto of Bize (France), dwelling-places of the men of the old stone age have been found by the hundreds. In many of them lived at one time or another men of the Crô-Magnon race. It must not be presumed, however, that every home was decorated by the tribal artists. These men of Magdalenian days were predominantly hunters and art was but the avocation of a few. Indeed, it appears that their art galleries and studios were things apart from their homes, for much of the best work was done in the deeper recesses of the caverns in places that were far removed from the family hearths.

Whistler, in his "Ten o'clock," describes the first artist as:

"This man who took no joy in the ways of his brethren—who cared not for conquest and fretted in the field—this deviser of the beautiful who perceived in nature about him curious curvings, as faces seen in the fire—this dreamer apart, was the first artist."

Kipling voices the same sentiment when he makes the father of Ung say to his artist son:

"Thou hast not toiled at the fishing when the sodden trammels freeze,
Nor worked the war boats outward, through the rush of the rock-staked seas,
Yet they bring thee fish and plunder—full meal and an easy bed—
And all for the sake of thy pictures." And Ung held down his head.

"Thou hast not stood to the aurochs when the red snow reeks of the fight;
Men have no time at the houghing to count his curls aright:
And the heart of the hairy mammoth thou sayest they do not see,
Yet they save it whole from the beaches and broil the best for thee."

No one who has ever seen the animated and spirited figures that adorn so many cavern walls can believe that the men that drew them were anemic "stay-at-homes" and obtained their experience and feeling from the mere sight of the carcass which their bolder brothers had dragged into the shelter to be cut up, skinned and roasted, nor even that their knowledge was derived from a hunt in which they had no part. Indeed, quite the contrary impression is gained. The hands that drew the animals must have often struck the fatal blow, and the minds that created the pictures might well be the same ones that had many times skilfully trailed the quarry and driven it into hidden pits or miry ground.

From the many caverns that contain engravings and pictures there are two especially well known which will serve to introduce the art of the cave-men. One is the cavern of Font de Gaume in the district of Les Eyzies, the other the cave of Altamira, in the Cantabrian Pyrenees of northern Spain. Inasmuch as it was at the latter place that the discovery of paleolithic paintings was first made it will be considered first.

The cave of Altamira is not far from the city of Santander. The discovery of the cave and its contents was due to two very innocent parties, a dog and a child. Long ago the entrance to the cave had been sealed by a landslip and its existence was unknown until a hunter and his dog passed that way. The dog, in running a fox to ground, widened the burrow and showed the hunter that it led to a cave. Years afterward, a Spaniard, Marcelino de Sautuola, who owned the estate in which the cave was situated, became interested in the crude man-made flints which he had found in the cavern débris.

One day, accompanied by his little daughter, he was seeking for

implements in a portion of the cave where the limestone roof came within a few feet of the floor. The child, able to stand upright without bumping her head, wandered aimlessly about while her father searched the cave earth for specimens. Suddenly she cried out: "The bulls! The bulls!" Her father looked to where her finger pointed and saw a marvelous sight. Painted and engraved on the ceiling was a conglomeration of animals, deer, horses, wild boars and bison, the latter greatly predominating.

The world gasped when Lord Carnarvon entered the inner chamber of Tut-ankh-Amen's tomb and gazed on objects which no human eye had looked upon for nearly 4,000 years. But to this little daughter of Spain was given the privilege of looking at an art that had been concealed for four times that stretch of years.

Cartailhac and Breuil, the eminent European archeologists, say that these pictures "place the old painters of the glyptic ages far above the animal painters of all the civilizations of the classic East and Greece." No matter how much art critics may quarrel over this statement, the fact remains that the ceiling of the Altamira must always be a shrine to artists who are modest enough to believe that all art did not originate with them.

Looking at the ceiling as a whole several salient features appear. There is no attempt made at grouping. It can not be called a picture; it is rather a collection of pictures painted on the same rock canvas. The figures are not all completed. Here and there appear head profiles and body contours which were started but never finished. It is like a sketch book of an erratic artist. Another interesting feature is that some engravings have been superimposed on others. Perhaps the most striking thing, aside from the pictures themselves, is the use to which the artists put the uneven surface of the stone roof. The ceiling is studded with protuberances of limestone. The artists cleverly seized upon this feature to enhance the life-like appearance of their representation of the animals. Many of these bosses were oval and presented an excellent background on which to paint bison in a recumbent position.

A brief description of a few of the better executed animals is all that can be given. Of the bison we will select three. One is painted in black. The outline is perfect. The whole figure is covered with black pigment toned in such a way that the effect of relief is excellent. The legs are well drawn and in good proportion. There is even an attempt at shading so as to give the appearance of its shadow being cast on the wall behind it. It stands erect straining on its hind legs. Another bison is shown lying down with its head turned backward, an unusual posture in primitive drawings and one which is difficult to do well. The head and

rump are placed on protruding knobs of stone which accentuates the relief. The color use is not natural, as it is of a brilliant red shade. The chef d'oeuvre of the cavern is a bison over five feet long. It stands erect with head lowered slightly. The coloring is superb. The contours are mostly in black, while the body is filled in with red beautifully toned. Patches of black appear on the body not for shading purposes but to show the different color of the hair. Four shades of color are blended in this animal, and thus it represents the acme of polychrome art. Its perfection is, however, marred by the awkwardness of the fore-limbs. They are in good proportion, but the hoofs are placed sidewise instead of pointing forward.

Of the other animals the best representation is that of a wild boar. This also is five feet in length. It is in rapid motion and is a vivid picture of the woodland boar leaping forward in full flight. The body is painted in light pearl-gray, with the outline sketched brokenly in black. The belly is tinted a delicate flesh color and shadings of black appear on the head and rump. The typical curled tail of the animal is well executed.

There is also a very fine engraving of a stag at Altamira. The lines are very finely drawn and one has to be rather close to it to see it at all. The fore-legs are correctly but rather weakly sketched, and the lines of the hind quarter are not complete. The pose is excellent and the long backward sweep of the antlers magnificent. The horses that are represented are rather incomplete and are not to be compared with the other animals.

The greatest art gallery of Paleolithic time that has yet been found is in the cave of Font-de-Gaume in the district of Les Eyzies in the Dordogne region. It lies well up on the side of a small valley where it joins the valley of the Beune. The limestone cliffs are sheer and bare, and deeply lined joint planes give them the appearance of great blocks. There is a long gallery that extends inward to a distance of nearly 500 feet. The vestibule and the first part of the corridor contain nothing of importance. At a distance of about 75 feet the rock walls begin to close in on one another until but a narrow passage separates them. After the visitor has brushed by the stalagmitic obstructions the picture galleries begin. Two painted bison stand guard at the entrance to the pictured halls. A little farther on is the Grande Galerie des Fresques which contains processions of bison and mammoths. Reindeer are also plentiful. There is one place where two reindeer are drawn facing one another, which may be an accident or may represent a composition. If the latter, it is an unusual feature of Paleolithic art.

A striking characteristic of these frescoes, but one which is quite

common in cave painting, is the superposition of animals on other animals. Take the fresco of mammoths, for example. The first impression is that mammoths alone are represented, but closer inspection shows that the mammoths are drawn over other paintings. In one case a mammoth overlies the drawing of a reindeer which is in turn painted on a bison. In some cases such figures have been blended together so by the fading colors that it is difficult to define each one clearly. The artists that did the work of superposition should not be too severely criticized, for in most cases they drew the more recent pictures on a smaller scale and thus retained the outlines, at least, of the earlier paintings. There has been much speculation as to why this method was pursued. The simplest reason seems the best. There was just so much wall space that was fitted for their art. Hence the late-comers were forced to use the same canvas. True artists as they were they preserved as much of the old art as possible by reducing instead of enlarging their own pictures, an appreciation and courtesy which later artists have not always shown.

About half way between the narrow place previously mentioned and the end of the cavern a lateral gallery runs to the right at right angles to the main corridor. At its end is a little hall which contains nearly a dozen bison in polychrome. This little chamber also contains a most grotesque caricature of the human face.

The cave of Font-de-Gaume contains the greatest variety of animals that has yet been found. Besides those mentioned are the cave bear, a lion, wolf, rhinoceros, wild boar and horses. To these animals must be added the human head, stencils of the human hand and lines that are supposed to represent huts. As was the case in the Altamire cave the bison predominate. It is of great interest to note the appearance here of the mammoth. Their great number means familiarity, which indicates that at one time, at least, the climate was quite sub-arctic.

Another animal which bears testimony to the rigor of the climate is the woolly rhinoceros which is painted in red. This animal is fairly well drawn. The small eye and the characteristic horns are well shown, but the articulation of the limbs is poor. This is especially true of the fore-feet, which are fused together, forming a stump. The artist makes use of a unique method in producing the contour of the body. This is accomplished by sketching parallel lines downward from the back and upward from the belly.

The outlines of the mammoths are all well done, as are also the heads. The bodies, however, leave much to be desired. This is probably due to the difficulty in depicting the long shaggy coat which concealed much of the body contour. This coat, however, is

always indicated by a fringe of fine lines that are drawn on the body a short distance from the belly line and hang down, concealing all but the stumpy appearance of the feet.

The wolf is represented only by the head and neck. It is a striking painting because of its treatment. The background consists of a bright red color on which the outlines were drawn in black. In the light cast by torches the effect is startling. The wolf seems to leap out of a hidden recess. The collar of black fur along its neck is very effective. A bear is very poorly done, but its lack of form is partially atoned for by its spirited position. It is standing on its hind legs in a most realistic attitude. That these artist-hunters knew the horse is attested to by four drawings, none of them remarkable in technique.

Before we leave the cave of Font-de-Gaume mention must be made of the reindeer, a favorite subject with the artists. It is said by some who have made a study of paleolithic painting in many caverns that the two deer that face one another constitute the finest painting that primitive man made of these animals. Both are painted in dull red, which is admirably toned to bring out the contours. The bodies, the antlers and pose are splendid, but the limbs are badly done. With the exception of the one on the right the articulations are most obscure and even in this one the hind limbs are the only ones that show any attempt to indicate the place of juncture with the body.

We have briefly and most inadequately described some of the engravings and drawings of the best known caves of southwestern Europe. Several questions arise to which suggestive answers must be made. What materials did the cave-man use to paint his animals? Why did he seek the innermost recesses of dark and dangerous caverns to ply his art? And finally why did he draw at all?

Fortunately, the caves themselves have yielded the answer to the first question. In them have been found his engraving tools, his colors already mixed, the flat bones he used for his palette, and his canvas. All are there save his brushes.

Without attempting to enumerate the paraphernalia of his art and to tell the localities where each bit of evidence was found, let us in fancy follow the ancient savage while he reproduces in quiet and dimness the animals that he had hunted with boisterous cries and shouts in the full sunlight of his native land.

Two men enter the cave, one the master, the other the neophyte. In their hands they carry stone lamps filled with tallow obtained from the very bones of the animals that are to be painted. In the tallow moss wicks burn, giving off a flickering but not an exceedingly smoky flame. They seek a place where the rock wall is suit-

able for their work. The first step is to wash the stone free from adhering clay and thus prepare the surface. The surface thus cleaned, the painter reaches into his artist's kit-bag of deer skin and takes out a handful of small chipped-stone implements. He selects the coarser one to engrave the profile line on the softer limestone. When the outline has been made he takes a finer flint and draws fine lines where they are needed. Now he is ready for the coloring. Wrapped carefully in another bag are hollow bones filled with ocher, red, yellow and brown. Other bones contain black carbonaceous matter in powdered form, while still others contain white and dusty clay. But the bag is not emptied yet, for there still remains a mass of marrow fat. When this is extracted the master is ready to prepare his colors. On a flat shoulder bone of one of the larger mammals the dry powder from the bone tubes is mixed with the marrow to the desired consistency and shade. Now all is ready for the application. The youthful assistant holds the lamp so that the flickering rays fall full on the rock panel. The master stirs the thick mixture with a stick whose end has been chewed in shreds, or one tipped with feathers or even bristles of the wild-hog, or hair from the shaggy mammoth (no one knows), and with bold strokes begins his work.

The questions why he chose the inner portions of the cavern and the motives that led him to paint at all are closely allied to one another. We will consider them together.

Practically all the finest paintings are of animals that were used for food. The exceptions, such as the bear, lion, wolf and others, are, for the most part, poorly done. Aside from the wolf's head at Font-de-Gaume, they are mere crude sketches. Again, many of the game animals are painted with arrows penetrating their bodies in the most vulnerable places, as the heart region. Other scenes suggest the multiplication of game and hence the continuation of the food supply.

The importance of the game to these hunters can not be overemphasized. Once a primitive people establish a certain diet, it is most difficult for them to depart from it. This is especially true when the game also supplies the household needs and even tools and weapons. Years ago a Sioux warrior said to an army officer stationed in a fort on the upper Missouri, "The buffalo is our friend. When he goes all is over with our people." The truth of this statement is brought home to us by an enumeration of the things that the buffalo supplied. Besides food, it gave clothing, tents, blankets, beds, leather for lariats, hide for boats and a shroud for the death journey. Nor was this all; its horns were used for flasks and ornamental headgear and its teeth were often strung in

necklaces. Indeed, without this beast the Sioux would have been in a sad plight.

An age-old custom and one which is still practiced among many primitive tribes of to-day is the practice of magic to ensure the obtaining of food. Whether the Magdalenians practiced such magic is of course not known. But the study of their pictures makes such interpretation as least possible. The wounded animals drawn on the dark cavern walls may have been so drawn that the powers of magic would assist the hunter in bringing down his quarry. The same principle was exercised by the North American Indian who, as Frazer tells us, "believed that by drawing the picture of a person in sand or clay and then pricking it with a sharp stick or doing it any other injury they inflict a corresponding injury on the person represented. A similar superstition is indulged in to promote and increase the food supply. The females are spared as much as possible in the hunt and magic is resorted to by drawing pictures that bear upon the multiplication of game." We can not escape the fact that such drawings are numerous in the Paleolithic caverns.

It is a short step from magic to priestly rituals which rapidly became esoteric in character. This readily accounts for the use of the deepest and most inaccessible parts of the caverns for the locations of shrines and magic manifestations. Reasonable as such conjectures may be, there are some facts that raise objections to their complete acceptance. It may be that pictures were made on the shelter walls or just within the entrance and have since been obliterated by weathering. Many caverns show indications of human occupancy near the entrance; hence the unusual condition of having home and temple under the same roof is encountered. Thus it may be that these ancient painters were merely artists for art's sake.

There are many other questions about the life and habits of our ancestors of the stone ages that come swarming to one's mind. We can never hope to obtain full answers to all of them, but when one considers the vast amount of reliable information that has been discovered, especially during the last twenty years, one must needs believe that other veils will be lifted which will admit us to further knowledge.

THE MARRIAGE OF KIN

By PAUL POPENOE
COACHELLA, CALIFORNIA

EVERY now and then two healthy, happy young people announce that they intend to marry. Because they happen to be cousins, there is an immediate uproar among the relatives of the lovers. Gray heads are shaken ominously; the curse of Heaven is prophesied on the marriage. If the children resulting from it do not turn out to be feebleminded deaf-mutes, it is predicted that they will at least be marked by other evidences of degeneracy and defect, which will leave their presumptuous parents' heads bowed in lifelong grief.

In a good many cases, the aspiring lovers are frightened out of their intention. In more cases, they go ahead, with lovers' usual indifference to advice, and marry. Thus there are probably few of the older American families in which at least one cousin marriage can not be found.

In due time babies put in their appearance. Usually nothing is wrong with them; all the relatives agree that they are type specimens of infantile perfection, and the evils of cousin marriage are forgotten until the next proposed match is announced, when the old wives begin their clamor again. The prevalent opinion is embodied in legislation, which in more than a third of the states makes marriage between first cousins illegal. Oklahoma extends the prohibition to second cousins.

A study of the customs of other peoples, past and present, shows that among most of them consanguineous marriage of near degree has been forbidden or regarded as undesirable; and in many instances the fear of resulting defective progeny seems to underlie the prohibition. The tabu may be carried to such excess as in China, where the marriage of two persons with the same surname is forbidden.

On the other hand, it is not difficult to find instances where consanguineous marriage is common, even in the closer degrees which are now universally regarded by civilized people as incestuous and horrifying. Thus, among the ancient Hebrews, Sarah was Abraham's half-sister, and Moses sprang from a marriage between a nephew and his paternal aunt, while even in the time of David a marriage between brother and half-sister was regarded as permissible (II Samuel 13:13), although it had been forbidden by the levitical code.

Neither Moses nor Isaac, products as they were of incestuous unions, can be described as a bad recommendation for the system. They were not marked by any "stigmata of degeneracy." But the most extraordinary evidence as to the biological effect of the marriage of kin is to be found in ancient Egypt, where matings between relatives of the closest degrees were both common and fashionable, and data on them are available during a period of at least 2,000 years.

Gods set the example, Osiris having married his sister Isis. Common people followed this example, but it is to the royal family that one can turn for most satisfactory evidence, since contemporary biographies and portraits of the rulers are available, and in many cases the actual mummies of the individuals are extant for examination. The results of such an examination, made by the late Sir Marc Armand Ruffer and published in his *Studies in the Paleopathology of Egypt*, are of too much interest to be left buried in pages seen only by a few special students.

For royalty, consanguineous marriage was almost a necessity, due to the fact that throne and property were inherited through the woman—mother or wife—as legal head of the house; while on the other hand the man was charged with responsibility for the actual executive work that devolves upon a monarch. It was very doubtful, as W. Flinders Petrie says, "whether a king could reign, except as the husband of the heiress of the kingdom." The only way, then, to keep the royal power in the family was for the nearest male descendant of the king to marry the heiress, who was likely to be his sister. This curious state of affairs is no doubt largely responsible for the fact that in genealogies of the dynasties one brother-sister marriage after another is found, the list varied only by the occasional introduction of a slightly more remote relative.

The XVIII dynasty, which ruled Egypt in the sixteenth, fifteenth and fourteenth centuries before Christ, probably represents as high a point as Egypt ever reached, and it is accordingly the one chosen by Dr. Ruffer for detailed study. It began when the Hyksos were driven out of the country. These hated invaders were nomads who had held Egypt for some 200 years: it was in their time that the Israelites settled in the Delta. Ahmose I, founder of the dynasty, drove the foreigners out of the kingdom and made it more secure against future invasion. Artistically, his reign is marked by commencement of restoration of the great architectural monuments of Upper Egypt.

He married his sister; their son Ahmenhotep I extended the empire by reconquering Nubia, repelling the Libyans, and carrying an invasion of Syria as far as the Euphrates river. So much vener-

ated was he by the people that divine honors were paid to him for 600 years after his death.

He, too, married his sister. Their daughter Aahmes married her half-brother Thutmose I, who consolidated his father's work in Nubia and Syria, and was a noted builder at home.

The daughter of these two, Queen Hatshepsut I, married her half-brother Thutmose II; she overshadowed her husband and was the actual sovereign. She proved to be a wise ruler of far-reaching influence—the greatest queen of Egypt.

She was succeeded by her nephew and stepson Thutmose III. This monarch's character, says J. H. Breasted, "stands forth with more color and individuality than that of any king of early Egypt, except Akhnaton. We see the man of a tireless energy unknown in any Pharaoh, before or since; the man of versatility, designing exquisite vases in a moment of leisure; the lynx-eyed administrator, who launched his armies upon Asia with one hand and with the other crushed the extortionate tax-gatherer. . . . His reign marks an epoch, not only in Egypt, but in the whole East as we know it in his age. . . . He built the first real empire, and is thus the first character possessed of universal aspects, the first world hero." And he was the product of five unbroken generations of brother-sister marriage.

This great king married his half-sister, and their son Amenhotep II was a man of extraordinary physical strength, who claimed that none of his subjects could bend his bow. His reign was marked by energy and military success. He married Tiaa, whose pedigree is uncertain, although she has been called his half-sister.

Their son, Thutmose IV, was an energetic lion-hunter in his youth and a successful leader in war after he ascended the throne. His marriage to a Babylonian princess resulted in a son, Amenhotep III, who succeeded to the throne. As there were no more kingdoms within easy reach to be conquered, his reign is marked by great development of the pursuits of peace—by expansion of commerce and patronage of the fine arts. He took a Syrian princess as his bride; their son Akhnaton, characterized by religious enthusiasm and a high moral standard, brought the dynasty to an end.[1]

Summarizing, Dr. Ruffer observes: "The characteristics of the XVIII dynasty were . . . tireless energy, which enabled Egypt to resist its foreign foes, to carry the Egyptian flag abroad, and to establish wise government at home; and an enlightened taste for the fine arts, most forcibly shown in the artistic reforms of Akhnaton. In these nine generations, issued from consanguineous marriages, there is no diminution of mental force. The energy charac-

[1] He was succeeded by his step-son, the well-advertised Tutankhamen.

teristic of Ahmose I is found 200 years afterward in Akhnaton, used, it is true, for different objects and higher ideals, but as intense in 1375–1358 as it was in 1580–1557 [B. C.]."

Of the specific evils popularly attributed to consanguineous marriage, one is infertility. Data are lacking to compare the fertility of the members of this dynasty with that of other families of the same period, but it is certain that the fecundity of the royal family was not below normal.

Again, children born of consanguineous unions are sometimes said to be short-lived. While the average duration of life in Egypt in that period is unknown, it is easy to ascertain the longevity of the male rulers of this dynasty. Eight of them show an average of 44 years, which is not bad, considering the stress to which a military ruler is subjected.

The physical proportions of these rulers, as measured on their mummies, are good—many of them were men of notable strength. "There is no evidence to show that idiocy, deaf-mutism, or other diseases generally attributed to consanguineous marriage ever occurred among the members of this dynasty, and as far as can be ascertained from mummified bodies, masks and statues, the features of both men and women were fine, distinguished and handsome."

"The result of this inquiry is that a royal family, in which consanguineous marriage was the rule, produced nine distinguished rulers, among whom were Ahmose, the liberator of his country; Thutmose III, one of the greatest conquerors and administrators that the world has ever seen; Amenhotep IV, the fearless religious reformer; the beloved queen Nefertari, who was placed among the gods after her death; Aahmes the beautiful queen, and Hatshepsut, the greatest queen of Egypt," the dynasty ending in Akhnaton, who is credited with being the first monotheist and monogamist among the rulers of his country. "There is no evidence that the physical characteristics or mental power of the family were unfavorably influenced by the repeated consanguineous marriages."

The kings and queens of the XIX dynasty, which followed, were probably lineal descendants of the foregoing. "Rameses II, the great historical figure of this dynasty, married two of his sisters, and had four children by the first and three, or possibly four, by the second. He is said to have married two of his daughters, but the evidence on this point is not conclusive. By other wives and concubines the king is said to have had 106 other sons and 47 daughters, therefore this descendant of a long line of consanguineous marriages can not be said to have been infertile."

A thousand years later another dynasty, of wholly different race, offers additional striking evidence on the effects of the mar-

riage of near kin. This is the dynasty of the Ptolemies, founded after the death of Alexander the Great by his bold and patient general Ptolemy Soter. The first four kings of this series were not sprung from consanguineous marriages; it is, therefore, particularly useful to compare them with the later rulers, among whom brother-sister matings had become customary.

The general reputation of the Ptolemies is of course bad: morally they were of the conventional type of Oriental despot, wicked and unscrupulous. But they were not weaklings: whatever their moral defects (for which environment must receive some credit, as well as heredity) they displayed abundant physical and mental energy. The direct line of the Ptolemies came to an end with the twelfth ruler of the dynasty, "not because the women had become barren, or the men unable to beget children, but because all the male descendants born in legitimate wedlock had been killed or exiled."

The sceptre was taken up by Auletes, an illegitimate son of Ptolemy X, and was finally laid down by his daughter Cleopatra VII, whose fame in history is sufficiently great, although not altogether spotless. It must be remembered, however, that public opinion as to her character has been based either on the accounts of her contemporary enemies, or on those of a long line of romancers, ranging in calibre from William Shakespeare and John Dryden down to the latest writer of vaudeville songs or "Sunday Supplement" thrillers. Nothing can be said against her character until she fell into the hands of two old roués, first Julius Caesar and later Mark Antony. She came to the throne a young girl, facing the impossible task of preserving her country and dynasty from the conquering power of Rome. Lacking military strength, she relied on blandishment and intrigue; and her amours with Caesar and Antonius must be regarded from this point of view among others. It is not necessary to attempt to whitewash the character of Cleopatra or that of any of her long line of incestuous ancestors, in order to establish the fact that, almost without exception, they demonstrated physical and mental energy, reasonably long life if they did not meet with violent death, and absence of the defects which popular prejudice attributes to consanguineous marriages of a much more remote degree than those here considered. Dr. Ruffer's summary seems to me well balanced:

> The Ptolemies born from consanguineous unions were neither better nor worse than the first four kings of the same family issued from non-consanguineous marriages, and had the same general characteristics. Their conduct of foreign affairs and internal administration was in every way remarkable and energetic. They were not unpopular in their capital, and the Alexandrians

rallied round their ruler when the Romans entered Egypt and resisted the foreigner

Though much has been written about the awful sexual immoralities of the Ptolemies . . their standard of morality was certainly not lower than that of their fellow townsmen.

The children from these incestuous marriages displayed no lack of mental energy. Both men and women were equally strong, intelligent, capable and wicked Certain pathological characteristics doubtless ran through the family. Gout and obesity weighed heavily on the Ptolemies, but the tendency to obesity existed before the consanguineous unions had taken place

The male and female effigies on coins are those of very stout, well-nourished persons. The theory that the offspring of incestuous marriages is short-lived receives no confirmation from the history of the Ptolemies . . . Omitting those who died violent deaths, the average length of life of the Ptolemies was 64 years

Sterility was not a result of these consanguineous marriages. No case of idiocy, deaf-mutism, etc, in Ptolemaic families has been reported

In these two noteworthy dynasties, close inbreeding was practiced on a larger scale, for a longer period of time, than in any other cases known to me in detail in the human species. None of the evil results generally attributed to cousin marriages seems to be manifested The consequences more nearly recall the results achieved by live-stock breeders, who long ago discovered and applied the fact that close inbreeding is the foundation of all great breeds and families of domestic animals.

Scientifically, the effects of inbreeding are now well understood They represent merely the union of similar heredities; for instead of possessing wholly different inherited traits the two mates are, by virtue of their common ancestry, possessors to a greater degree than usual of the same inheritable units.

Thus, if the ancestry of the two is good, their children will be benefited by receiving a double dose, so to speak, of certain good traits of their ancestors. When the parents are carefully selected, as by a live-stock breeder, who culls out all the animals with bad qualities, there is no quicker way of building up a fine breed than by inbreeding. In the dynasties which have been chronicled above, the stock was in a way selected at the start—only select and superior individuals would have been capable of founding dynasties under the then existing conditions. By theory, good results would have been expected from the inbreeding of such selected stock, and in fact it appears that the results were, on the whole, excellent.

On the other hand, in a stock that carries defective heredity, the children are doubly handicapped. Moreover, it often happens that a hidden trait in the family ancestry is brought to light, when two related lines of descent are united in a single individual: thus a feeble-minded child may be born in a cousin mating, where feeble-

mindedness was latent or recessive in the ancestry and had not previously made itself manifest. It is cases like this that have given consanguineous marriage its ill repute, although recessive traits may also appear most disconcertingly in the offspring of unrelated persons, if the same trait happens to occur in the ancestry of each.

Defective children born after a marriage of kin were naïvely explained by the supposition that there was something inherently wrong about the marriage of relatives, when in fact it was the ancestry that should have been blamed In passing judgment on a proposed marriage, therefore, the vital question is not "Are they related by blood?" but "Are they carriers of desirable traits?"

In a stock that is defective to start with, consanguineous marriage brings the evil traits to light with surprising rapidity The archives of heredity are full of pedigrees, gathered for the most part in poor farms, jails and other custodial institutions, where almost every member of a family, for generation after generation, is tainted in some way. When it is found that numerous cousin marriages are represented in such a pedigree, it is altogether natural that these marriages should be looked on with suspicion

Biologically, then, the marriage of kin may be a good thing or a bad thing It depends on the kind of germ plasm these kin have received from their progenitors. If the same congenital defect or undesirable trait does not appear in the three previous generations of two cousins, including collaterals, the individuals need not be discouraged from marrying if they want to.

But, from a broader point of view, the strictly genetic considerations are not the only ones to be weighed in passing judgment on consanguineous marriage. Other considerations are sometimes not given the weight that they deserve.

Some of the opposition in modern civilized countries to consanguineous marriage is doubtless a survival of the establishment of prohibited degrees by the Roman Catholic church during the middle ages. The extent of these prohibitions went far beyond the limits which any biologist would have set: a well-known survival, only lately abolished by Parliament in England, was the prohibition of marriage between a man and his deceased wife's sister.

Without stopping to inquire the real motive for the erection of these bans to marriage between blood relatives or sentimental connections, one may recognize the validity of the argument by which Roman Catholic theologians now justify them, namely, that the kind of love which leads to mating and the kind of love which binds the members of a family together are two different things which should not be mixed Psychologically, this proposition will be indorsed by almost every one. In late years particularly has it been

pointed out that too great attachment between members of the same family, originating in youth, imposes a heavy handicap on the personality, ever vainly seeking to free itself from the cramping influence of this emotional bond in order to take its place in the outside world

Eugenically, on the other hand, it is desirable that the individual be trained to look outside his own family circle for a mate, because in this way new and, presumably, valuable family traits will be brought into the stock; and latent undesirable traits will be denied the expression that they might get if two persons, related and hence carrying the same trait, should marry.

Quite apart from the biological aspect, moreover, it is evident that normally a young couple are better situated, if they have the counsel, influence and help of two different family circles to fall back on, than if they have only the one in which they were together brought up

In summary The study of these extraordinary Egyptian genealogies is of great interest to the biologist, because it affords such a striking confirmation of the theory of genetics. But it offers no encouragement to the establishment of consanguineous marriage as a normal rule In isolated cases in healthy stock, cousin marriages are not to be opposed—they may even be recommended Charles Darwin, whose children are the offspring of a cousin marriage, is one of the standard illustrations But, at best, a cousin marriage usually connotes a narrow horizon and lack of opportunity on the part of the mates to meet a wider circle of eligible young people, and one of the cares of parents should be to give their children as wide a circle of eligible acquaintances as possible, in order that sexual selection may have full play.

As to consanguineous marriage in general, then, and particularly the closer degrees of it which go by the name of incest and are criminal under the laws of modern civilized nations, the case seems to be fairly clear The individual's interest agrees with that of the race in requiring, at least after the period of adolescence, that the individual's affections should be projected out of the home and family and not confined within them.

METEORITES

By Professor ARTHUR M. MILLER
UNIVERSITY OF KENTUCKY

METEORITES, being solid bodies which come to earth from celestial space heated to dazzling brilliancy on the surface from friction with the air and detonating with terrifying intensity as they set up violent atmospheric compression and rarefaction waves, would appear to carry with them proofs of their extramundane origin as incontestable as could well be demanded Yet it was not until the closing years of the eighteenth century that the scientific world became convinced of the reality of these objects and that they did actually "fall from the sky." It is said that even President Thomas Jefferson, progressive though he was in the science of his day, was skeptical about such occurrences, replying to the assurances of a friend that the actual fall was well attested by two Yale professors that he "would prefer to believe that two Yankee professors[1] would lie rather than that stones could fall from heaven "

It is all the more remarkable that skepticism should have prevailed as to the reality of these occurrences when one considers to what remote antiquity records of the falling of these bodies extend. Such a record we undoubtedly have in the reference in the book of Acts of the New Testament to the "image which fell down from Jupiter" at Ephesus, in the making of silver miniature replicas of which Demetrius and his fellow-craftsmen built up such a thriving business

Despite the fact that the aggregate number of meteorites (estimated to be between 600 and 700) which come to the earth each year seems to be quite large, very few people have been killed by them. Sir John Herschel, writing near the middle of the last century, is the authority for the statement that the number up to that time had been four. The only instances of death from this cause of which there has been preserved specific data are two—that of a priest or monk in Northern Italy in 1511 and of a person in India in 1827. This remarkably small mortality due to them strikingly demonstrates how infinitesimal is the space on the globe physically occupied by human beings in comparison with the remainder of terrestrial surface.

[1] Professors Silliman and Kinsley, in their report on the Weston, Connecticut, meteoric fall. Transactions of the American Philosophical Society, Philadelphia, Vol. 6, pp. 323, 325, 1809

THE BACUBIRITO, MEXICO, METEORITE

One of the largest meteorites known. Weight about 27 tons. From Dr. O. P. Farrington's work on "Meteorites" by courtesy of the author.

THE GREAT BACUBIRITO METEORITE
State of Sinaloa, Mexico, and the Mexican workmen who dug it out.

COMPOSITION AND CLASSIFICATION OF METEORITES

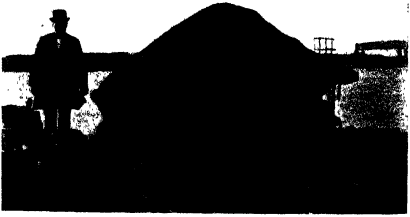
While meteorites have brought no new chemical elements to the earth, some of the combinations of elements in them are unique. In all some forty elements have been recognized in them, but fifteen of these are very rare. Most conspicuous is metallic iron alloyed with nickel, the latter usually forming eight to ten per cent of the iron-nickel alloy. Meteorites which consist entirely or largely of this iron-nickel alloy are known as "siderites" or simply "irons." The Anighito (if indeed this be truly meteoric and not simply basaltic, and hence telluric in origin), brought to the American Museum of Natural History from Cape York, Greenland, by Admiral Peary is such an iron, weighing about 36½ tons Another siderite in the same museum, the Williamette from Oregon, weighs 15 6 tons. There are a number of large irons (about six), from three to fifty tons in weight, which fell in northern Mexico. These were considered sacred objects by the Aztecs, and before the coming of the Spaniards a number of them with infinite labor had been removed to Mexico City, where they are still on exhibit. The largest of these Mexican irons—the Bacubirito—still lies where it fell in the state of Sinaloa. Dr Henry A Ward, under whose supervision it was completely exposed about or shortly before 1892, estimated its weight at close to 50 tons. It probably weighs about 27 tons.

All meteoric nickel-iron, when polished and etched with nitric acid, exhibits a characteristic reticulate crystalline structure, named after the discoverer, Professor Alois von Widmannstätten, of Vienna, the "Widmannstätten Figuren." This structure was considered an infallible test for metallic iron of celestial origin until

it was found in native nickel iron in basalt on Disco Island, Greenland, by Baron Nils Nordenskiöld in 1870. The finding of such iron of undoubted terrestrial origin, some of it in masses weighing as much as 20 tons, and in the same general region as the "Peary Irons" found at Cape York, Greenland, has, according to Fridtjof Nansen, raised serious doubts as to the meteoric origin of the latter, though they have been accepted as genuine by the best authority in this country and placed on exhibit in the American Museum as including the largest in captivity.

There is little doubt but that the human race first learned the use of iron from sideritic masses of celestial origin. Significant in this connection is the structure of the ancient Damascus sword blades, celebrated for their toughness and flexibility. They possessed a laminated reticulate structure closely resembling meteoric iron. First made from iron of celestial origin, to which such structure was inherent, Damascus blades, as the makers learned to obtain iron from terrestrial sources by smelting and to substitute it for meteoric iron, were so wrought as to retain the simulation of this original laminated reticulate structure: "None genuine unless branded throughout the brand."

Another group of meteorites consist largely of silicates of magnesium, calcium, aluminum, etc., through which are disseminated



CAPE YORK SIDERITE
Weight 36½ tons Dr. Henry A. Ward "about to lift it." From photograph as it lay in the Brooklyn Navy yard, courtesy of Dr. E. O. Hovey.

specks of metallic nickel-iron. These are called "aerolites." On account of their lighter specific gravity and the grayish, stony appearance of their interiors, they are commonly referred to, in distinction from "irons," as "stones."

There is another and smaller group of meteorites intermediate in character between the siderites and aerolites, known as "siderolites," in which the iron constitutes an irregular lattice or mesh work with the stony matter filling the meshes. Sideritic structure grades into aerolitic through siderolitic.

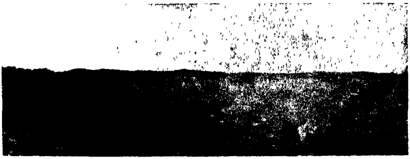
According to Professor George P. Merrill of the National Museum, Washington, D. C., there had been catalogued to January 1, 1919, for the world, 788 distinct falls. Of these, 367 would be classed as "irons," 403 as "stones," and 31 as belonging to the intermediate group. Of the 367 irons, there have been seen to fall 17, or less than five per cent; of the 403 stones, there have been seen to fall 354, or nearly 88 per cent.; and of the 31 belonging to the intermediate group, there have been seen to fall five, or 16 per cent. This disparity in the number seen to fall in the different groups, especially when the irons and stones are compared, calls for an explanation. One theory is that iron meteorites, though really less numerous in the soil than the stony, are, on account of their metallic nature, more readily detected than the latter. A farmer, plowing, or a workman, digging a ditch, is very apt to stop to examine any metallic object his plow or point of pick may strike. In case this should happen to be a meteorite, even though not recognized by the finder as such, it is laid aside as a curiosity and, sooner or later, its real character is detected by some one. A stony meteorite struck under the same conditions is to the one who turns it up simply a stone and nothing more. Professor Merrill, however, is not satisfied with this explanation, calling attention, for one thing, to the greater destructibility of the irons through oxidation, and he is disposed to champion the view that there has been in recent geologic times an actual decrease in the number of falls of iron meteorites, or, as he puts it, there has been in that time a "decreasing basicity in meteorites."

The late Professor William H. Pickering, of the Harvard Astronomical Observatory, Cambridge, Massachusetts, offered still a different explanation. Calling attention to the facts that many more iron meteorites have been found in the western than in the eastern hemisphere (nine times as many in proportion to the stony meteorites, a matter that appears to have been overlooked by Professor Merrill), that on the western hemisphere are concentrated most of the *large* irons and that all irons large and small have never been found buried to any great depth in the soil, he held that all or most of

these irons fell at one time and that this time was comparatively recent. The agent he invoked for broadcasting them is a comet, the head of which, composed of masses of nickel-iron, he thought "side swiped" the earth on its western hemisphere side in such a way as to cause the brunt of the impact to be borne by the northern part of Mexico and adjacent portions of the United States. Here has been found, much of it in large masses, the greatest amount of meteoric iron known from any other region of equal area in the world. Here, too, near Canyon Diablo in Arizona, is the famous "Coon Butte Crater," a circular depression about 600 feet deep (originally probably 1,400 feet deep) surrounded by a raised rim about four fifths of a mile in diameter, which, in the character of the raised rim and the vitrified and pulverized sand forming the floor, possesses all the characteristics of a crater of impact, as much so as any of the shell craters made by the heavy projectiles fired from German guns in northern France during the late world war. These characteristics and also the fact that large quantities of meteoric iron, amounting in all to date to 15 tons, have been found scattered about this crater early led American geologists to accept the comet-impact-theory as the most satisfactory explanation of this remarkable phenomenon. Now has come forward Professor Pickering with additional support for its comet origin (though only the effect of a small portion of the comet), derived from a study of the distribution of iron meteorites over the surface of the earth.

Pre-mundane History of Meteorites

It appears to be almost certain that meteorites, some two or three of which the average person is entitled to see fall to earth within the period of an ordinary lifetime, constitute the heads of small comets. The very minute particles that trail along after the heads of large comets, constituting in part the tails of them (but if they



Coon Butte Crater, Arizona
From photograph, courtesy of Dr. George P. Merrill.

are recurring ones and have been running in their courses a long time, distributed well around their whole orbits) on being heated to incandescence and dissipated by friction with the air, produce the phenomenon of "shooting stars," several of which any one may see shoot across the heavens on almost any clear night.

This meteoric material is known to be travelling at very high velocities—some of the larger masses at rates as high as 26 miles per second, and some of the dust-like particles at rates as high as 45 miles per second. Now 26.16 miles per second is the "parabolic velocity" for celestial visitors to our solar system. That is, it is the maximum velocity a body falling towards our sun can attain by the time it reaches the distance from the sun of half the diameter of the earth's orbit, even though it may have been falling from the utmost confines of space. In other words, a body may have been falling towards our sun from so far away that it has been falling forever, yet this is a velocity that, at the distance of the earth from the sun, it can not exceed. Noting this accord between the common velocities of meteorites and certain comets, astronomers were formerly disposed to look upon all meteorites and comets as originally extraneous to the solar system, having been attracted into it from very remote distances. The less than the parabolic velocities possessed by some of them, resulting in their moving in elliptical orbits, was accounted for by retardations produced by perturbations of the planets. Quite recently, however (see announcement in *Science* for January 19, 1923), Professor Stroemgren, royal astronomer of Denmark, as the result of mathematical investigations made on comets for the last twenty-two years, seems to have refuted this old idea that comets (and presumably meteorites also) are "vagrant wanderers from interstellar space," and proven to the contrary that those with elliptical orbits have always formed a part of our solar system. Those that he finds moving in parabolic or hyperbolic paths he accounts for as outcasts from our solar system, through their once closed elliptical orbits, having been thrown into open curves by accelerative perturbations of the planets

Granting, then, that meteorites (and comets) have always formed part of our solar system, what has been their history within that system? A partial answer to this question is to be found by a study of the structure of meteorites. It is quite certain from such study that they have not always been cold bodies flying through solar space, but must have at one time been molten and subsequently cooled under great pressure. This is evidenced by their coarse crystalline structure and their occluded gases. Even CO_2 in a liquid condition in minute cavities has been found in some of them. Such facts can be accounted for only on the theory that

meteorites (and comets) once formed the interiors of large planetary bodies or of a former sun. These facts harmonize well with the Chamberlin-Moulton theory that our present solar system is formed out of the wreck through "tidal disruption" of a former solar system, the disrupting agent being another and much larger sun, in proximity to which our former solar system at one time came. In accordance with this theory meteorites are fragments of this former solar system—planetesimals out of which our present solar system is still being built.

Effects of Collision between the Earth and Meteorites

The paths which the earth and a meteorite are pursuing around the sun may intersect, and it may happen that both these bodies arrive at this intersection at the same time. This will result in a collision which will be head on, tail end or at some angle in between, the effective velocities in any case being sufficient to heat through friction with the air the outside of the meteorite to incandescence. As the outside melts it is rubbed off by the friction, leaving the brilliant, but usually quickly disappearing trail that is the conspicuous phenomenon in the case of every meteor The only evidence the meteorite retains of this melting when it reaches the earth is a thin surface glaze, which is darker in proportion to the basicity of the body, and also a fluting formed of disconnected impressions, like thumb marks, which radiate from the point directed forward in its passage through the air. The friction of the air and also the cushioning of it in front of the rapidly moving body quickly slows down its initial velocity, so that, except in the case of a very large meteorite, which would almost certainly be iron, this velocity is entirely checked before the body reaches the earth. At this point of checking, usually at a height of from eight to twelve miles, the meteorite (in nearly every observed instance a stone) breaks up with loud detonations, and the main mass and its fragments drop to earth with accelerating velocity of bodies falling from this height under the influence of gravity. The smaller fragments, on account of the more effective resistance of the air, often have so slight velocities on reaching the ground that they do not penetrate the surface even of soft ground, and have been known not to break ice only a few inches thick.

Meteorite Hunting

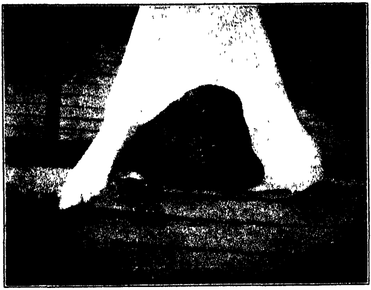
The writer has been engaged with some measure of success for twenty years in endeavoring to run down and locate any meteorites which in descending to earth have come within his horizon. The first one of these, which he was fortunate enough to be able to

observe through its whole visible course and measure the altitude and azimuth of its point of bursting, was on November 15, 1902, at 6:45 in the evening. By requests inserted in the press of Kentucky he was able to secure four other observations which gave the same data as seen from other widely separated places in the state. A plotting of these observations indicated the knobs of southern Bath County, Kentucky, as the place where this meteorite should have fallen, and almost immediately came word from that section that a fragment of it had been picked up by one Buford Staton from the road in front of his cabin, where it had fallen. This was secured by the school superintendent of the county, Mr. Daugherty, and sent to the University of Kentucky for examination Dr. Henry Ward, who was then alive, was notified. He came to Lexington and purchased the stone from Mr Daugherty for $200. It weighed 13½ pounds Professor Henry C. Lord, of the Emerson McMillin Astronomical Observatory, Ohio State University, Columbus, Ohio, also saw this meteorite descending low in the southern heavens, and through the public press called for observations. Combining the replies which he and the writer received from numerous observers it was determined that this body was seen in its fall over a north and south belt some eight degrees in width, extending from middle Ohio to the Gulf of Mexico. Despite this north and south range of observation, the horizontal component of the meteorite's path was from west to east. The apparent contradiction involved in these facts is reconciled by considering the time of day at which the meteorite fell At that season of the year (November) it was dark at 6:45 P. M., and many persons were out of doors along a north and south belt in that time zone, where conditions were favorable for seeing a meteor flashing across the sky. Further east the time of night was later, and not so many people were out of doors To the westward it was yet day where a meteor would not so likely light up the sky sufficiently to attract attention.

In 1919 the writer had another opportunity to study the phenomenon of a falling meteorite and recover some of the fragments. It fell near midday on April 9, and its horizontal component of fall was from south to north, coming into southern Kentucky from over the state of Tennessee. In the latter state, the sky was cloudless, and, though at midday, the meteorite shone with a brilliance above that of the sun. Over Kentucky hung clouds obscuring it from view, but, by this time, the stone was near enough the earth to be detonating with terrific violence so that its position from point to point could be located by the sound. Indeed, the concussions were so violent as to shake buildings, leading the county papers of that region first to report the phenomenon as an earthquake. These

vibrations in buildings were noticed a long distance from the point of fall, being detected as far away as Lexington, 85 miles to the north. In coming north over Kentucky, this meteorite's horizontal component paralleled the line of the Cincinnati Southern Railroad, and it is an interesting fact that the tower men along the line of this road as far as Danville kept by telephone ahead of this "commotion" coming up the road (that is, ahead of the sound of it). Fragments of this meteorite—an aerolite of remarkably low basicity—being composed in fact mainly of silicate of magnesium—began to spall off at Sawyer Post Office, near Cumberland Falls, and some 54 pounds of the material were secured by the writer from that vicinity. There is little doubt, however, that the main mass, which must be very large for an aerolite, went on farther north and to-day lies buried somewhere in the very rugged portion of Pulaski County, north of the Cumberland River

On May 30, 1922, at 7:30 P. M., central time, a meteorite with a west to east horizontal component passed over the states of Indiana, Kentucky and West Virginia. It was seen by a large number of people in those three states and also in Ohio and Virginia. The writer, in response to a request published in a number of newspapers, obtained records of observations from a considerable number of eye-witnesses in these five states, but, though these persons exhibited the most cordial desire to contribute information which would lead to the discovery of this celestial body, so few of them gave estimates of azimuth and altitude of the point of bursting or disappearance of the meteorite as seen from the point of observation couched in terms that were intelligible that little use could be made of most of the information received in calculating very exactly the place of its fall. There were, however, enough intelligible data received to enable the writer to select Greenbriar County, West Virginia, one of the most mountainous counties of the state, as the most probable one in which it came to earth. In pursuing meteorite hunting as a pastime, the writer is continually having it brought home to him how few adults, even those entitled to be placed in the intelligent class, when it comes to intelligible expression give any indication that their conception of the earth in its relation to the universe is any less primitive than that of the ancient Chaldeans, Hebrews and Egyptians, or of Voliva of Zion City. However stoutly these same people may assert their belief in the Copernican theory, practically their conceptions are those of persons living on a flat earth, covered over by a bowl-shaped solid sky, on which measurements may be made in feet, and travelling along which a celestial body, in passing to the horizon, comes to earth, usually not farther away than over the next hill, or at most, not beyond the



BATH FURNACE AEROLITE
Fell in Bath County, Kentucky, November 15, 1902. Weight 180 pounds.
From photograph by the author.

next county. Let us hope that when our present boy scouts come to maturity, having been trained in a proper knowledge of their relation to their physical environment, "meteorite chasing" may take on the aspects of a more exact science than it has to-day.

LEGAL CONTESTS FOR THE POSSESSION OF METEORITES

A number of interesting questions of ownership have been raised by the finding of meteorites. Where they have got into the courts, they have all been settled in favor of the owner of the land on which the meteorite fell, in accordance with the decision rendered in the first case of the kind in this country—that of Goodard v. Winchell, Supreme Court of Iowa, October 4, 1892. Professor H. V. Winchell, state geologist of Minnesota, had purchased for $105 a 66-pound aerolite from Peter Hoagland, who dug it up from the land of John Goodard, in Iowa, where it had fallen May 2, 1890. The decision rendered in favor of the plaintiff, Goodard, in the lower court, was reaffirmed in the Supreme Court on the ground that a meteorite became, by falling on land, as much a part of it as boulders transported thither by glacial action.

A question of ownership was raised in the case of the main mass of the Bath County, Kentucky, meteoric fall. Mr. Pergrem, resident of the knobs of southern Bath County, while squirrel hunting

in the early spring of 1903 on a large tract of wild land belonging to the "Ewing Heirs," noticed where the tip of a white oak sapling had been clipped off. Suspecting that this had been done by a piece of the meteorite, which, by its brilliant light produced and the terrific detonations occasioned, had so alarmed the inhabitants of the region in the previous November, he looked further and found a skinned place on another sapling. Lining up the direction as given by these two points, he noted where the meteorite would strike the ground, and, digging there, found a mass of iron weighing about 180 pounds, buried flush with the ground at the base of a small tulip poplar With the aid of an old horse, he removed the meteorite on a sled to his house. A more prosperous cousin, also named Pergrem, who knew the 13½ pound fragment had brought $200, then traded him a cow for this main piece. It was on the front porch of this more prosperous Mr. Pergrem that the writer, who a few days after this transaction had made a trip to the region in order to obtain, if possible, some facts bearing on the trajectory of the meteor, first saw this specimen, and secured a photograph of it. On his return to Lexington, he communicated to Dr. Ward the news of this new find in a letter which was forwarded to him in Russia, whither he had gone after another meteorite. In due time came a cablegram from Dr. Ward in St Petersburg, authorizing the writer to offer a certain sum for this latest and, evidently, main portion

THE WILLIAMETTE SIDERITE

Loaded on a truck, and the man and boy who thus "ran away with it."

of the Bath Furnace, Bath County, meteorite. In the meantime, however, the Ewing heirs had brought suit for possession of it, and Pergrem, the possessor, not wishing to face a lawsuit, relinquished all claim to it and demanded back his cow from his cousin. The matter remained in *statu quo* until the return of Dr. Ward. The case was then settled out of court by Dr. Ward paying the Ewing heirs $1,400 for the meteorite (there has been a big slump in the price of meteorites since Dr. Ward's death), with the understanding that $200 of it was to go to Mr. Pergrem, the finder. This fine specimen of an aerolite may now be seen in the Field Museum, Chicago.

Another meteorite over which there was an interesting legal contest was the Williamette iron already referred to. This specimen was found by a former Welsh miner, Ellis Hughes, on a tract of land adjacent to his own, belonging to the Portland Land Company At first, he thought he had discovered an iron mine, but on further digging, saw the mass was detached, and realized he had unearthed a meteorite. The next thing was to gain possession. He did this by means of a low, heavy wooden truck, especially constructed for the prospective load, on which he managed to capsize the 15-ton iron, and then, with no other motive power than an old

WILLIAMETTE SIDERITE

Weight 15.6 tons. From photograph, courtesy of Dr. E. O. Hovey.

horse winding a rope around a capstan as a winch, which had to be moved and re-anchored as the truck with its load was drawn up to it, he and his fifteen-year-old son, working so quietly that winter that no one, not even his nearest neighbor, ever suspected what they were doing, dragged this iron three quarters of a mile from the property of the Portland Land Company on to his own land—the only case on record, according to Dr. Ward, of "any one ever having run away with a fifteen-ton meteorite." Naturally, on its being noised abroad what this Welshman had discovered and secured, the Portland Land Company brought suit for possession. When the case came to trial, the lawyer for the defendant put up a most ingenious plea. He alleged that in this case the meteorite was not "real estate" but "discarded personal property" belonging to whoever might find it; that it was an "Indian relic," known and revered from time immemorial by the then virtually extinct tribe of Siwash Indians. In support of this claim he introduced on the witness stand a very old Siwash Indian, almost the last of his tribe, who testified that this mass of iron had long been known to members of his tribe, who attributed to it magic virtue—that even as a youth he had been conducted to it by one of the old medicine men, and had it explained to him how, if arrows were dipped in the water that collected in the hollows of this iron and were then shot at game, they always went true to their mark. However, the judge, holding true to precedent, as all judges do, and citing the Goodard v. Winchell case, ruled that the meteorite went with the land, and issued a writ, placing it in possession of the Portland Land Company, from whom it was afterwards purchased by the American Museum of Natural History.

THE TIME OF DAY[1]

By Professor ALFRED H. LLOYD
UNIVERSITY OF MICHIGAN

First Part

I

"Pray, what time is it? Watchman, what the hour?" Some one replies, giving minute as well as hour. Or this: "The Twentieth Century of the Christian Era." So do little things of life and big, one's watch and history often come together. However sententiously, the wonderful hovers over the commonplace.

Whatever the time by hour or by century, it would seem safe to say that by some happy conjunction of circumstances, including the stars, we are all living in our present time, at this very minute or hour, or more grandly, we and millions of others the world over are contemporaries. Yet, so soon as said with seeming safety and also impressive as it really is to contemplate, is it after all quite true? Are even you, reader, and I and all our present fellow-beings necessarily contemporaries? True, by the clock on the mantel or in yonder tower or by the date, 1923, we are all in our own time and it certainly seems to be the same time; but are we and all our so-called contemporaries, far east or far west, north or south, are we, all of us, really of this present time? Do we, all of us, live now actually and responsibly? Are we, in our will and our action, not just in our existence, on time?

Beware of clocks. Beware of calendars; of mere chronometers and outwardly and abstractly accurate chronicles of all kinds. Too easily they give false notions; perhaps imparting unwarranted confidence and pride of progress, perhaps giving needless discouragement. Clocks and other formal histories have a certain nicely intellectual and instrumental value; also we all like to hear them tick or strike; we all like to hear of roundly numbered centuries and eras; but such formal times is not real time. The real twentieth century is a responsibility, not a date that merely "has it one better" over the nineteenth; and, in general, actual time and of course also actual space are what they are only relatively to the facts and to the meaning and life of them. Einstein, if I have at all under-

[1] This essay had its origin in an address given in March of the present year before the members and friends of the chapter of Phi Beta Kappa at Vassar College. The original address is here considerably revised and expanded.

stood him, would hold even the sun and the earth, the moon and the stars and the light from or to any of them to tests of time and space, not by mere abstract chronometer or cosmometer, but by the facts; by relative weights, then, not by mere formal and absolute measures. Not tarrying, however, for his thanks, just as an adventure of my own I insist that, whatever be true of space, real time is not the simple, tick-tock, straightforward and accurately datable thing we are in the habit of thinking it. Whenever two or three are gathered together in time, the time of their meeting very often suffers curvature or distortion of some sort. Thus, I submit that people there are to-day—are you, reader, and I, however obviously now come together, of their number?—who are straining the supposed integrity of time terribly by living actually, whatever the objective time-registers may say, either a century or two in the past or, as if with an equal but possibly compensating violence to timeliness, a century or two in the future.

If we must have reactionary and ghost-seeing conservatives, it is doubtless very fortunate that we get also impractical and futuristic dreamers. Whenever certain and radical changes are imminent and a distinct transition is the great sign of the day, both those groups do serve a purpose. At least, either alone would be disastrous and the conservation of life and its attainments and possibilities that the two together insure is plain. Moreover, the life of a people, when so divided between one untimely and distorting extravagance and another, opposing and balancing this, admittedly has a peculiar zest and vitality. It brings an analyzing and always very instructive and productive experience. There is, too, always something doing. But, to utter the obvious, such a divided life lacks singleness and directness and positive efficiency. To have half the people behind the times and the other half ahead of the times may be good education for progress, but it can not effect it. Sooner or later the people as a whole must become single-minded and be mobilized to the appropriate purpose of their day.

To-day our ghost-seeing reactionaries and our not less extravagant and abnormal visionaries certainly need at last to realize not that by the time-register this is the twentieth century, since they are all over-complacent with such a large round number and its three ciphers, but that the twentieth century really means something specific and exacting. Through some agency of liaison they must get together and give full and honest heed to the facts and values of the time they have inherited, to the visible attainments of mankind and to the real, however still latent, opportunities of the present life. All must give up the peculiar excitement of living at once in opposing groups and out of date and try the greater ex-

citement of being open and active contemporaries and really on time.

Surprising how hard it sometimes is actually to live in and of one's own time! How hard, and how worth while! The old ways tempt some, the established and privileged. Protest, attack and destruction occupy others who are suppressed and discontented and who will have their hopes and dreams. But timely action is worth while for all.

II

So, once more: What time is it? Twentieth century of the Christian Era, the watchman has called. Did he add that all was well? I failed to hear quite that. Disturbances in the market-place or down that side street may have confused things a bit. Perhaps all is not quite well. But, apart from the mere counting, what means this twentieth century?

With some of us seven-thirty means breakfast and the pleasant aroma of coffee. Other times of the day also have just such specific meanings. In the evening eight may mean an interesting book or perhaps for some the glare of the movies. But the present century? This is not so easy and the answer I shall give may quite lack aroma or glare or anything to hold attention. Thus, if at once I may leave the shallow waters, in ways which I propose to consider at some length and which in spite of possible difficulties I hope to make more interesting than any momentary aroma or glare, the twentieth century of the Christian Era means: (1) Anthropology, including especially psychology and implying generally man and his nature studied scientifically and exposed very intimately; (2) technology, including especially artifacture—instead of manufacture—often to the point of automatic machinery, man's burden of work taken off his shoulders and carried in ever-increasing amount mechanically; and so (3) new and great adventure. A date, I believe, hour or century, always means adventure! In those ways, then, our century would seem to have made a date with us. Are we going to keep it? Have we the courage of the adventure? There is the challenge.

With all my warning and preparation my grandly "ological" way of tolling out the century may only puzzle. This I can not help. All know that these are days of amazing and amazingly large things, taxing the understanding at every turn. But a short time ago we were measuring things in hundreds and thousands; to-day, with effort, in billions. Every thing is big, very big, except the world, and this somehow the big things have made small, very small. Civilization has reached so far as no longer—except at far

north or far south—to have a frontier. History has gone back even beyond the prehistoric. Must occupy us, then, however puzzling, however "ological" or in any way grandiloquent, really large ideas and comprehensive standpoints. To-day, if ever, one has a right to ask that people accommodate their mind's eyes to large views. Mere technical philosophy may not be a crying need of the hour; but, whatever the effort required, at least fundamental ideas are. Long enough have we been meeting our various problems of life in conventional and superficial ways; direct, frontal attacks have had their day, including certain years of war and the long impatient years since; demanded now the flank movement of getting behind the lines or beneath the surface, which only comprehensive ideas can possibly effect. So, while many may still wish to toll the present century with more sound than sense, I must hold to my 'ologies.

These 'ologies I shall discuss in order as the large, important events of the day, anthropology and technology; and then, thirdly, I shall try to indicate the new and great adventure of our time.

III

In the first place, then, ours is an era of anthropology, the intimate naturalistic and scientific study of man. The great intimacy of the science is best seen in its two very significant branches, psychology and psychiatry, now natural sciences.

You and I are accustomed to this science even in its more intimate forms. Many of us, however, may never have appreciated all of its implications and in particular its significance historically. On the whole until about forty years ago man was protected from the intruding intimacies of science. In respect to what distinguished him from things and other creatures he was an object of interest theologically, morally, even abstractly and rationalistically, but not scientifically and naturalistically. Persons born since 1900 may have to think twice before they will at all appreciate the change that has taken place. Now the intimate anthropological science of psychology is in the company of the natural sciences. In Ann Arbor we have what in spite of the passing of the years we still call the "New Science Building." It contains the laboratories, class-rooms and special libraries of four natural sciences: Geology, botany, zoology and psychology. This very series suggests a sort of advance of natural science on man. But the newness of our building might be taken as referring, not just to the building, but to the inclusion of psychology. Fledgling from the warm, human nest of mental and moral philosophy, psychology has run off to the very different habitat of natural science. How the excellent Noah Porter, D.D., author of the once widely used

"Human Intellect" (1868), "Science of Nature vs. The Science of Man" (1881) and "Moral Science" (1885) would scurry to the bank of the pond of science and frantically call on psychology to come back to dry land and spiritual safety. No clamor on the bank, however, can bring the lively and ever stronger science back. Psychiatry and psycho-analysis have been added to its activity, as if diving to swimming, and, while time must pass before the new science and its applications to life will be clearly realized, the event has taken place and stands out as something of great importance to be faced and appraised. Some years hence the historians will be chronicling how such close, scientific study of man happened. The narrative of one of them we may read in imagination even now:

It is peculiarly interesting to record that in the later nineteenth and earlier twentieth century there were those who discovered with a completeness not before supposed possible most intimate correlations between the body and the mind of man and, as even more noteworthy, who succeeded in applying the methods of natural and experimental science not merely to the study of man in his physiological character but also to the study of his consciousness, of his knowledge and will and feeling. At the universities laboratories for such study sprang up almost like mushrooms. Journals of physiological, genetic, comparative and experimental psychology, as well as of many other phases of scientific anthropological inquiry, were published. In a word the study of man, long in large measure theological or with the waning of theology only abstractly rationalistic, came to be most closely associated with the natural sciences and it appeared as if man's long persistent aloofness from nature had been abandoned. The effect on his institutions, on the conduct of his life politically and economically, socially and morally, was of course tremendous, but was not fully appreciated for some time.

So runs a part of that future record. Several pages further on I have found also this interesting comment:

The movement for an unreserved scientific anthropology, notably rapid and successful in America, at first seemed to supply valuable fuel for the fires of materialism and fatalism, but in the end actually proved to be a source of real incentive and opportunity to mankind and so of distinct spiritual progress. Can truth, however disturbing at first, ever have any other outcome?

The fact or event, then, of our time being what we have so recorded for us, what fully and exactly does it mean? To understand it fully and properly, we must of course face it candidly, the intimacy and exposure, the realism and apparent materialism of it; but especially must we take clearly into account the history, the long history, by which it has come about. Some overlook this history or even deliberately turn their backs on it. How blind they are or how foolish so to betray a great heritage. Their folly must not be ours. Some years ago I was at luncheon with a gentleman

of great artistic interest and sensibility, a virtuoso superlatively. I ventured to comment on the color, specially fine and intriguing, of the walls of his dining-room.

"Yes," he said, "it certainly is unusual. What is more, I have peculiar satisfaction in it. I took great pains to get it. On these walls my decorator put twenty coats."

"Surely," I exclaimed, "there was some experimenting, some waste."

"Experimenting, yes; but no waste. I feel, as I look, that every one of the twenty coats, even the first, is present in what you and I see now."

He had a more sensitive eye than I. His claim, however, must help us to comprehend why our own time, just to appraise itself, must know fully its past. You and I may not be up to date, we may not really qualify as our own true contemporaries, unless we actually sense or catch the contributing, however now hidden, traditions of a long history in what we now behold or now do. Our anthropological, often intimately psychological interest, methodical and naturalistic and scientific in its expression, is indeed late come and it is what it is, unique, *sui generis*, but we must remember that necessarily it is the product, as it were, a latest coat made subtle by many others before it, of nearly twenty centuries of preparation. Duly appraised, this present is a great memory. So knowledge of the earlier coats and of the progressive and dramatic order of them is necessary if we would know the last and would appreciate the new life that in our own time this last coat either has made already or is to make possible.

"Was there one for each century?" I hear some worried person ask. Possibly. But I shall shorten the whole record to four.

IV

In four single words hear the record of Christendom's history: Theology, mechanics, biology and to-day's anthropology.

"Mere jargon of some cloister," says some one; "Why haven't we by this time outgrown the cloister? Mere language of an academic curriculum." The charge is true. May every age have its cloister or its "classic shades!" In those four words lies an important human story for him who will give attention. Do you see nothing in their given order? The gradual breaking down of man's reserve and aloofness from nature? Do you fail to see the successive standpoints and key-ideas that have made our history not merely intellectually but also in the important practical affairs of morals, politics and economics? Do but consider:

First, theology in the Middle Ages, regulating life narrowly and

dogmatically through the aloofness of a theocratic, doctrinal and legalistic institution, Christendom's first device for law and order, for system or mechanism, directly man-powered and militaristic, the medieval church, an institution of morals, politics and economics all in one and all aloof and as supernatural as unnatural.

Next, in the seventeenth and eighteenth centuries, solar mechanics and mathematics with regulation of life from the nearer sun, a distant but at least no longer invisible and supernatural source, with a temporal and secular natural institution, the state, claiming at least equality when not superiority to the church, appropriating the church's methods of regulation and insisting at least on temporal power as its peculiar prerogative, and with a distinct regard to reason as native to man and to law as natural.

Then, in the nineteenth century, man come still nearer nature, biology, revealing a unity and a certain essential orderliness of all life and by these and the special hypothesis of evolution bringing man and the natural world not yet completely but still more closely together, enriching the great idea of nature's mechanical or, as it was in spirit, institutional order with the even greater idea of the living organism, wherein mechanism became versatile, adaptive, even supermechanical, and under influence of which among other effects, monarchical absolutism and rigidity gave way to the orderly adaptability, the organic movement of democracy. The practical effects, generally known and appreciated, of biology and evolution on actual life have certainly been no greater, for their time, no more momentous, than were those of the mechanics in the previous era.

And to-day, lastly, aloofness and reservations apparently quite gone, anthropology and psychology candidly naturalistic and scientific and in their directness and candor also bound in momentous ways to affect our practical life of affairs, giving us what in the language of the movies might be called nature's own "close-up," even an exposure, as intimate as natural, perhaps as offensive as good for the soul of man.

How aloof was man at first, presuming to live aside from nature and always in view of the yonder and hereafter. Now, not just formally or mechanically, as for a time, nor yet only biologically, the somewhat closer way which followed, but most intimately, in the very intimacy of his consciousness and reason, of his passion and will, how one with nature he is being made to appear!

Does any one still find in that quaternion—theology, solar mechanics, evolutional biology and intimate anthropology—only a catalogue of names for scholastic learning? Does any one still fail to catch the story, the great dramatic story, whose eras it recites?

At risk of being wearisome with what may be a needless elaboration, I am going to indicate the motive and character of the story in several ways as follows. Thus, most obviously and almost repetitiously on my part, it shows Christendom in process of a gradual adaptation to the natural environment; then it shows important expansion and liberation, the spirit of life repeatedly breaking away from an established order or letter; and, finally, it shows moral experience and growth involving frequent struggle and disaster but also continued attainments. When these aspects of the story of Christendom have been made clear, we ought to be able to understand the particular mark of our own time, with which we are now so concerned, our present scientific anthropology and the implications and memories which enrich it.

V

The medieval theology and its aloof institution hardly suggest even in possibility or preparation anything like adaptation to the natural environment. Yet, with no intent of disrespect in my secular terms, the medieval church may well be looked upon as a strategical retreat on man's part. Let us call it that, then, and allow a change of the metaphor in a moment. In those troublous times, when the structures and instruments of the pre-Christian civilizations had scarcely one stone left upon another, one part in orderly relation to its neighbor, man met the disorder, the intellectual and moral and political chaos, with the excellent device of a super-mundane supernatural institution, St. Augustine's "City of God." Into that he withdrew, taking for preservation what treasures of the past he could take, things and memories. The long threatening storms raged. "The rain was upon the earth forty days and forty nights." The floods rose. Like the Ark of old, the Church rode the storm, saving man and his past and with disciplines, with mental and spiritual exercises of all sorts preparing him for the future. Time came, when the protected life within could once more go out on dry land and in more direct and positive way undertake to solve the problems of the disturbed environment. There was, of course, a significant clearing of the sky and subsiding of the violence, when Galileo—as the dove bringing the olive leaf! —discovered the orderly heavens and in general, with Newton in good time adding evidence, the dependable mechanism of physical nature. Personally, I have often wondered if those discoveries of the astronomers had ever been made without just such a preparatory discipline of mind and character as the Church had provided. Say what one will, in the long run only orderly and controlled persons can reason within themselves or find convincing law and order in the world around them.

From Galileo's time on man had and showed more confidence of earth, feeling more at home and by all sorts of ingenious mechanical applications gaining an ever increasing and widening mastery of earth, safely exploring all the seas, exploring, settling and exploiting the continents, possessing first the earth's surface, then its more intimate resources. The biology and then the anthropology and psychology that followed the earlier mechanics only served to carry forward the adaptation and this came at last to be, as some one is sure to say, thinking doubtless of Freud and other very scientific psychoanalysts, adaptation to the point of hopeless loss of the human self in the natural, in the material and sensuous if not sensual, so that even the term "close-up," suggested already, would seem hardly adequate.

The historic "illumination" and exposure of selfish and sensuous human nature in the eighteenth century was but a candle flame or a smoking torch compared with the electric light and X-ray of present analyses and revelations of man's very soul. Of that earlier exposure writes one historian:[3] "There was nothing left but matter —a wholly unspiritualized mass. Sensuous greeds and needs on all sides! Individuality, grossest self-seeking, the law!" Witness "the licentiousness of the miserable court which demanded slavish obedience," the "tyranny and hypocrisy of a priesthood rotten to the core" and an "administration of the state, a dispensation of justice, a condition of society, that must revolt to the utmost every intellectual principle and every moral feeling of man." But to-day, so far has man's naturalization gone, as now registered not just by a historian but by scientists, even soul itself is sex or, as a bit better, nutrition and sex. Could naturalism and its exposure go farther? With some success, too, those who see the adaptation as ending in a complete surrender to physical nature may press their case. Yet, so much granted, the whole truth can not be told so. Facing the unquestionable physical naturalism of the time, I find myself somehow reassured when I reflect that such a sensuous realism, while never without its dangers, has not always been in bad company. Early and evangelical Christianity, at least after St, Augustine, certainly has even cultivated a very distinct sensuous and physical realism. Witness so much in the vocabulary of orthodox Christianity. Possibly our own present realism and materialism, culmination of Christendom's gradual adaptation to the natural environment, has its own spiritual meaning and purpose.

Nor, having said so much, can I refrain from saying more. It must have some important bearing on the full meaning of the adap-

[3] Schwegler in his "History of Philosophy," translated by J. H. Stirling, p. 188.

tive process with its interesting successive eras and its present outcome that in the minds and hearts of men God seems to have had a way of always identifying himself with the sphere of life which at any particular stage man has recognized. He has followed the accepted law and order. With Galileo's science and its discoveries, for example, God actually left the traditional church and, if the mystical and nature-loving saints or the pantheists generally, whether religious or philosophical, may give testimony, reappeared as the spirit or genius, the presiding ruler, of the new system. With Darwin, again, and the evidences of evolution, there came to expression a still broader and deeper pantheism; God was so expanded as to be identified with or declared immanent in the great unity of all life. So, by the history of Christendom's growing pantheism, God has kept company with man through the long process by which man has been finding himself in nature and even the extreme naturalism of our day may not be as hopelessly unspiritual as some regard it. To speak now only as a historian, whatever may have been man's attitude, God at least has shown no fear of following the truth.

VI

Expansion and liberation also were said to be marks of the progress of Christendom. The expansive theism, or pantheism, by which God became ever more and more a free and comprehensive spirit, less and less a locally and officially residing and presiding deity, ruling life from outside and above, we have already remarked. But, this aside, in the life of Christendom, now under one formal order or system, now under another and broader, there appear to have been certain critical times, closely corresponding to the eras which have been indicated, when to all intents and purposes, as his experience has enlarged, man has heard and eventually has heeded the cry of an expanding and freeing life. "No longer the narrow and formal letter, but the more vital, the more open and at same time deeper spirit." Surely something of that sort must always accompany adaptation. Successful adaptation must be quite impossible without plasticity and to secure this an old habit or system of life, in short the letter that killeth must constantly yield to the spirit that setteth free: St. Augustine's narrow institution, for example, of the middle ages, exclusive and aloof, to Galileo's or Newton's broad and more efficient helio-centric mechanism of nature; nature's mere physical mechanism, again, to Darwin's still more plastic or versatile and adaptive organism; and this, as the years pass and still another order cometh, to the modern psychologist's also natural but still freer conscious and willing individual. Just to be

able to see in these changes not violent revolutions but expansion and liberation of the spirit, in other words to see them as enlargement and fulfilment, not betrayal, of the cherished past is helpful in many ways and here particularly with respect to finding the past and its memories, however long removed and however refined by generalization, in a present that many are finding strange and offensive.

Words, words, words! Theology, mechanics, biology and anthropology over and over again! Institution, mechanism, organism and natural but conscious individual! Why not tell of changing political institutions, economic development and moral and spiritual growth? Why not speak out of a life of actual affairs? What are "adaptation to environment" and "liberation of the spirit" compared with actual exploration and occupation and exploitation of the earth, with wars and battles, with diplomatic as well as military triumphs, with royal splendors or tragic martyrdoms, with epoch-making inventions overcoming space and time, with expanding commerce and industry, with all kinds of "broadcasting," with a whole world of isolated localities become, as many have been calling it in effect, if not always in recognized form, a single community politically and economically and morally, suggesting such a social unit as the Greek city-state or the church of St. Paul, "members one of another"? What indeed are they if not the same thing! The histories of political and economic and moral conditions would all certainly show within each context adaptation and expansion and liberation of the spirit.

VII

Here, while still proceeding with our purpose, we may enjoy a little diversion, helpful especially to those who to a diet of 'ologies and other wordiness prefer concrete—I mean things that are concrete. Cruthers, I believe, in one of his essays has dubbed this the concrete age. It is that, although Cruthers did not get so far as to quote in evidence the modern psychologists and very realistic psychiatrists.

The life of Christendom was said to show, besides adaptation and liberation, moral experience and growth involving struggle and disaster but also attainment or arrival. I propose, then, to explain this by telling a very simple story—for the concrete-minded. A story, even when as true as this I am to tell, may be not without pleasant relief for everybody. Only now I would that some twentieth century John Bunyan would take up the narrative for me. I can merely indicate the opportunity that certainly awaits some capable raconteur.

Well over nineteen hundred years ago Christian set out on his

long and arduous journey through the centuries and no ordinary journey has been his. Adventure after adventure befell him as he passed from one country to another, from one outlook on the world to another. Over and over again body and mind and character were assailed. With every discovered opportunity came danger, often extreme disaster. Suffering was his portion with every real accomplishment. We of to-day in our own despair, seeing misery in so many parts of the world, complacent prosperity and inaction, our post-bellum pacifism, in other parts, might well take courage from his example. So often he fell prostrate and it was as if he would never rise. As often he was seen again up and on his way. Were I speaking in dream or allegory I might tell of meetings with Pliable and Timorous and Mistrust, with Ignorance and Blindman, Violence and Love-Lust, with Breed-Hate and See-Red, with Faith also and Knowledge, with Persistence and Do-Well and Never-Die, and with many others, some delaying and misleading, some instructing him wisely, inspiring him with new vision and setting him on his forward way. My tale, however, is no such imaginary one, albeit skilful fiction might better serve my present purpose. Real characters were met by Christian, well-known kings and emperors, popes, great soldiers, bankers, artists, thinkers—such as St. Augustine, Galileo, Darwin, William James—and leaders of all kinds. In each group, I may go so far as to say, some were followers of On-Mischief-Bent, some of Do-Right and Know-the-Truth and not always did Christian keep the better company. Whenever new vision came to him and new adventure opened he always found himself between license and freedom and, as we to-day can well understand, was hard beset to know the real difference, often mistaking one for the other. He came, for a conspicuous example, to the time of the brilliant, over-lighted Renaissance, a tragic time for him morally, a tense one intellectually, as potent with danger as with hopeful adventure. I have often to wonder how he ever survived. Most corrupt popes and Macchiavellian princes were against him. Cunning intellectuals bewildered him. Cynical candor assailed the faith and courage that had been his. A sensuous literature intrigued him. Still, at one time helped by reading Dante's story of the development of a human soul and his beautiful sublimation of romantic love and at another, when in despair he had stopped in one of the great churches, hoping for quiet if not for real support, by a glimpse of fair nature through an opened window, and, again, inspired by Galileo's heavens that anew declared the glory of God, he did manage in each instance to take up his pilgrimage and proceed on his forward way. Then, near the very end of his journey, which apparently could not be very far from our own time, his plight was once more a sorry one, far sorrier indeed than it had ever been before. Break-Things tempted him. Be-Normal and

Stop-Thinking—here I have to be allegorical—actually bound him for a time hand and foot. But, whether with good warrant I shall not try to say, he did gain hope and determination for real freedom and progress from his memories of the deliverances which had been his so many times before.

There is a dramatic story for some skilful narrator. But enough now if you see in Christendom's journey through the centuries, not a mere ordinary history of one thing or another, but a spiritual pilgrimage with adventure and abundant disaster yet with accomplishment also. A spiritual pilgrimage, I have said, and at once somebody may wonder. How may we speak of a spiritual pilgrimage, at all analogous with that recounted so wonderfully by Bunyan as "from this world to that which is to come," if the materialism, the naturalistic, scientific realism of our time be the goal at which Christendom has arrived? Bunyan's Christian journeyed from earth to heaven, but Christendom, our Christian, as theology has gradually given place to scientific anthropology and intimate psychology, has journeyed apparently from heaven to earth. The question, then, is a fair one, as fair as natural, and of course it only brings back our persistent problem, the problem of the last coat: Is anything of Christendom's great past left? Is there anything spiritual, is there any spiritual gain in the sensuous realism of our day? In reply I only repeat from above that such realism has not always been in bad company. In due time it may be possible to say more. Suffice it now that Bunyan himself, as Christian enters heaven, has much to tell of the white robes of the angels, the shining glory, the sweetly ringing bells and wondrous music, the harps and crowns, and the real and sensuous magnificence generally. There was realism in very truth. With all that sensuous and realistic magnificence, too, with the glare of gold and the wondrous music I somehow have to connect the words with which the seventeenth century narrator woke from his dream:

"Then I saw that there was a way to hell even from the gates of heaven."

That, however, is another side of the story and I conclude my immediate reply to the questioner by indulging in a glittering and rather pious generality. For any one with a real faith truth can be the only way of life and heaven only a name for reality as the truth may reveal it. After all, for good or for ill, nothing can shine like reality and the shining realism of our day, the gold and the music, the sensuous reality generally, whether presenting heaven or revealing a way to hell, could hardly be expected to be such as Bunyan knew three centuries ago.

(To be concluded)

INFLUENZA AND THE WEATHER IN THE UNITED STATES IN 1918[1]

By Dr. ELLSWORTH HUNTINGTON

YALE UNIVERSITY

ASIDE from the Great War the influenza epidemic of 1918 was perhaps the most terrible calamity that has afflicted the world since the Black Death of the fourteenth century. The main epidemic has, as usual, been followed by minor epidemics, first a few months later, and then in each succeeding winter. There is real ground for the fear expressed by Sir Ronald Ross, the famous student of tropical diseases, that if influenza continues unchecked it may ultimately harm northern countries as much as malaria harms those of lower latitudes.

In studying influenza two of the important questions which confront the investigator are: Why does the disease break out so suddenly at certain times? Why does it vary so much from city to city?

As to the first question, no conclusive answer is yet available. Apparently, something occasionally stimulates the bacteria which cause influenza, and then for a few weeks or years they acquire extraordinary virulence. The stimulus may be in the external environment; or perchance all living organisms have fundamental physiological rhythms which cause them alternately to be strong and weak. The variations in virulence may possibly be due to changes in man's power of resistance. People may become susceptible to the disease because of their environment, or because between one main epidemic and the next there is time for them to lose whatever immunity they have acquired through having the disease or through carrying its germs, even though the germs never produce illness. Another possibility is that the severity of epidemics depends in part on the accidental coincidence of the rhythms of two or more kinds of bacteria. Still other possibilities might be mentioned. Many students are studying the problem, and some day we shall have a solution. As yet, however, we do not know what stimulates the influenza bacteria to pernicious activity; and hence we have no means of knowing when a new epidemic will appear or of estimating how severe it will be when once it has stricken us.

Concerning the variations in epidemics from place to place, we

[1] Based on the work of the *Committee on the Atmosphere and Man* of the National Research Council, a full report of which is published by the council.

know, for example, that during ten weeks at the time of the main epidemic of 1918 Philadelphia had a death rate from influenza and the resultant pneumonia four times as large as that of Milwaukee. The death rate in Pittsburgh was twice as great as in the neighboring and similar city of Cleveland. Till recently, however, we have had no conclusive evidence as to why such enormous variations take place from city to city. Certain new and important possibilities, however, have now been opened up by the work of Professor Raymond Pearl of the School of Hygiene and Public Health at The Johns Hopkins University and by the subsequent investigations of a Committee on the Atmosphere and Man appointed by the National Research Council. These investigators have compared the destructiveness of the influenza epidemic of 1918 in the large cities of the United States with the following factors:

A. Factors of human environment (demography).
   1. Age distribution of the population, that is, the relative number of inhabitants of various ages.
   2. Ratio of the sexes, that is, the number of females for every hundred males.
   3. Density of the population (number of persons per acre within the city limits).
   4. Rate of growth from 1900 to 1910.

B. Factors of geographical position.
   5. Distance from Boston where the epidemic began.
   6. Longitude.
   7. Latitude.

C. Physiological factors represented by the following normal death rates in 1915, 1916 and 1917.
   8. All causes.
   9. Pulmonary tuberculosis.
   10. Organic diseases of the heart.
   11. Nephritis and acute Bright's disease.
   12. Typhoid fever.
   13. Cancer and other malignant tumors.

D. Racial factors.
   14. Percentage of negroes, 1920.
   15. Percentage of foreign born, 1920.

E. Industrial factor.
   16. Percentage of population engaged in manufacturing, 1919.

F. Climatic factors.
   17. Mean temperature for day and night.
   18. Change of mean temperature from one day to the next.
   19. Absolute humidity, or actual weight of water vapor per cubic foot of space.
   20. Relative humidity, or percentage of possible water vapor.
   21. Weather—a combination of Nos. 17–20.
   22. Climatic energy—the energy or vigor that the general climate would be expected to give on the basis of the measured work done by factory operatives and students under different weather conditions.

Directly or indirectly these 22 factors embrace most of the conditions which may have been effective in causing people's power of resistance to the epidemic to vary from city to city. Sanitation and medical practice, however, fail to appear in the list because their degree of excellence can not easily be expressed in figures. But the death rate from typhoid fever is generally supposed to be an unusually good measure of sanitary efficiency, while other death rates are in most places a fairly good index of the excellence of the medical service. Almost the only important fields which the factors do not cover is that of variations in the disease-bringing bacteria so far as such variations are due to causes not included in our table. When all these various factors are investigated by means of the most exact and delicate mathematical method yet known, the only one which shows any conclusive causal relation to the destructiveness of this particular epidemic is the weather.

Let us review the steps by which this surprising conclusion has been reached. The method which has been employed is one of the great triumphs of mathematics. It is called partial or net correlation. The labor involved in this method is most arduous, but the results, when it is properly used, are beautifully clear and simple. The gist of the matter is that a complex phenomenon like variations in the death rate from influenza may be due in part to any one of many causes. Only to a very limited degree can we experiment to see which causes are effective, for man is too precious to be sacrificed lightly. Yet if we are to discover how to prevent or mitigate future epidemics, it is essential to obtain the facts which could be discovered by experiments. The essence of such experiments is that one of the conditions which may cause the differences should be allowed to vary, while the rest are kept constant. The observed variations in the death rate can then be easily compared with the variations in the condition which the experimenter is investigating. The method of partial correlation acts like such an experiment. It allows the mathematician to determine the effect that any one condition would have if all the others were kept constant. An illustration will make the matter clear.

Suppose that you wish to know what conditions really determine the speed at which you drive your automobile. You can try experiments, or you can keep for each mile a record of the conditions that are presumably important, including (1) number of minutes per mile; (2) roughness of the road on a scale from 1, very smooth, to 10, very rough; (3) number of vehicles per hundred square feet of roadway, which is more important than per hundred linear foot; (4) number of traffic policemen; (5) number of cross streets; (6) size of the city or town in which lies the given mile of road; and (7) width of the road.

At first thought one is inclined to say that the time per mile is increased by each of the other conditions mentioned above except wide roads. Partial correlations will show that this is not true. A rough road and the presence of many vehicles do, indeed, always tend to increase the time per mile. But if you are absolutely positive that there is no traffic either on your road or on the cross streets, if there are no traffic policemen, and if the road is smooth and wide, you drive as fast where there are many cross streets as where there are few. The size of the cities and towns is equally ineffective. You drive as slowly in the center of Rochester as in the center of New York, even though New York is nearly twenty times as large. That the size of the city is not in itself a determinant of your speed you can judge by driving through the streets of a big city and a little one at three o'clock in the morning. You go as fast in the big city as in the other, provided all the other conditions are kept constant.

But surely the wider the road the greater the speed. No, for city streets are almost invariably wider than the paved part of state roads out in the country. Yet on the narrow country road you drive thirty miles an hour with safety, whereas on the wide city street you often go no more than ten. If there were no traffic and no cross streets, you would not care whether the roadway was wide or narrow.

How about the policeman? Does he slow you up? Analyze your data by means of partial correlations. You will find that what chiefly checks you in the vicinity of policemen is the cross streets and the traffic, but the cross streets are important only because they carry traffic. If there is no one on the road, the policeman signals to you far away, and you pass the crossing almost without slowing down; if the traffic is heavy, the policeman prevents it from getting tied up. In the long run the policeman actually causes you to make better time than you could if he were not there. An analysis of your data by the method of partial correlation would be as conclusive as a series of experiments in showing that the really important factors are first, the roughness of the road and the number of vehicles per hundred square feet, both of which cut down your speed as they become more pronounced; and second, the policemen who increase your speed as well as your safety. The cross streets, the size of the towns, and the width of the road assume importance only through their relation to the volume of traffic.

By means of this precise mathematical method Professor Raymond Pearl of Johns Hopkins University has compared certain environmental conditions with the destructiveness of the influenza epidemic in 34 large cities of the United States. The first number in each line of Table II is the correlation coefficient between the

destructiveness of the epidemic during a period of 25 weeks and the condition named in that line, all the other conditions in the table being held constant. The second figure in each line shows the ratio between the correlation coefficient and its probable error. If this second figure is between three and four it suggests a relationship; if it rises as high as four it probably indicates a real relationship but does not prove it; while if it is more than six, the reality of the relationship is established almost beyond doubt, provided the method is applied correctly. A relationship, however, does not mean that one condition is the direct cause of the other, but merely that they vary together and would give a fairly large correlation coefficient. But if partial correlations are applied and the number of vehicles is held constant, the coefficient for size would fall to less than four times the probable error. We shall see that there is a similar fall in the apparent but illusory relation of the epidemic to latitude and to the death rates from all causes and from heart diseases.

TABLE I

Partial Correlation Coefficients between Death Rates from Influenza and Pneumonia for Ten Weeks in 1918 and each of six Environmental Conditions, when the other five Environmental Conditions are held constant

	Coefficient	Ratio of Coefficient to Probable Error
(1) Age distribution of population	0.132	1.2
(2) Sex ratio of population	0.161	1.4
(3) Density of population per acre	0.163	1.4
(4) Latitude of city	*—0.424*	*4.5*
(5) Longitude of city	—0.133	1.2
(6) Rate of growth, 1900 to 1910	—0.083	0.7

On the basis of this table, as Dr. Pearl puts it: "It can be safely asserted that in the determination of the variation among these 34 large American cities in respect to the excess mortality due to the epidemic, the age and sex distribution of the population, its degree of crowding, its rate of recent growth, and its distance west from the Atlantic seaboard played no appreciable part whatever." Latitude, on the other hand, seems in this table to play a significant part. The minus sign of its coefficient means that low latitude was associated with a high death rate. But latitude can affect people's health only through climate, or through some other condition which is influenced by climate. Professors Winslow and Grove have shown that the normal death rate is the factor through which latitude and climate appear to be related to the epidemic, for when the normal death rate is held constant, the apparent effect of latitude disappears.

Having found no cause for geographical variations in influenza

along these environmental lines, let us consider another set of correlations carried out by Professor Pearl. In Table III the destructiveness of the epidemic is correlated with each of several normal death rates, while the others are held constant.

TABLE II

Partial Correlation Coefficients between the Death Rate from Influenza and Pneumonia for Ten Weeks in 1918 and Six Normal Death Rates from Various Causes, When the Other Five Normal Death Rates are held constant

	Coefficient	Ratio of Coefficient to Probable Error
(1) Death rate from all causes	*0.405*	*4.8*
(2) Death rate from pulmonary tuberculosis	0.279	2.6
(3) Death rate from organic diseases of the heart	*0.537*	*6.6*
(4) Death rate from nephritis and acute Bright's disease	— 0.008	0.1
(5) Death rate from typhoid fever	— 0.138	1.2
(6) Death rate from cancer and other malignant tumors	0.268	2.5

Here, as in the other table, it is clear that most of the normal death rates had nothing to do with the severity of the epidemic. The popular view that the presence of tuberculosis rendered a population especially liable to the epidemic is shown to be false by the fact that the ratio at the end of line 2 is only 2.6, too small to be significant. If the popular view were true, New Orleans, Cincinnati and Baltimore would have been especially great sufferers from the epidemic, while Grand Rapids, Milwaukee and Rochester would have suffered least. As a matter of fact, Pittsburgh, Nashville and San Francisco had the highest mortality from the epidemic during the whole of the winter of 1918–1919, and Grand Rapids, Toledo and Indianapolis the lowest. In the same way, if the death rate from typhoid fever is as good an index of sanitary conditions as is generally supposed, the low figures in line 5 "bear out in precise mathematical terms what was obvious to the thoughtful and candid observer at the time of the epidemic, namely, that the severity with which a city was hit by the epidemic bore no relation to its general sanitary status or to the efficiency of its health organization." (Pearl). During the normal years, 1915, 1916 and 1917, Nashville, New Orleans and Atlanta showed the worst record from typhoid, while the best places were Cambridge, Boston and Chicago, all of which, and especially Boston, were very hard hit by the influenza.

On the other hand, the large figures in lines 1 and 3 suggest that where the death rate from all causes is normally high, as in

New Orleans, Albany and Baltimore, and especially where the population is especially liable to organic diseases of the heart, as in San Francisco, Washington, Albany and Boston, the influenza epidemic tended to be unusually fatal. Does this mean that in such places the population has some peculiar physiological characteristics whch render people susceptible to disease and especially to heart disease? Or does it mean that where there is a high death rate, especially from heart disease, there also happened in the fall of 1918 to be some other condition which allowed the epidemic to be unusually severe? The only conditions not yet considered which seem likely to be of importance and for which data are available are the percentages of foreign born, colored and factory workers in the population, the climate and the weather. All but the last of these are eliminated as soon as partial correlation coefficients are applied.

TABLE III

Correlation Ratios between Death Rate from Influenza Epidemic and Various Weather Conditions

I Days before or after onset of epidemic	II Temperature	III Change of temperature from one day to next	IV Absolute humidity	V Relative humidity
70–61 before	1.0	4.2[2]	2.0	1.5[2]
60–51 "	0.9	1.7[2]	3.6	3.5[2]
50–41 "	1.6	2.9[2]	3.6	2 9[2]
40–31 "	2.2	1.5[2]	1.6	1.1[2]
30–21 "	*6 6*[2]	— 0.6[2]	*8.0*	1.9[2]
20–11 "	*6 8*[2]	— 1.1[2]	*10.4*	— 0.4[2]
10–1 "	*4.8*[2]	— 0.6[2]	*7.0*	*5.5*[2]
0–9 after	1.4	— *5.3*[2]	1.5	1.1[2]
10–19 "	1.4	3.6[2]	1.9	1.7[2]
20–29 "	2 6	— 0.5[2]	2.7	— 0.8[2]
30–39 "	*8.1*	— 0.6[2]	*6.9*	— 0.1[2]
40–49 "	3.4	0.5[2]	4.0	— 0.7[2]

There remains, then, only the weather. In order to test its effect the Committee on Atmosphere and Man carried out a further investigation. For 36 large cities in the United States they took the death rate from influenza and pneumonia during the ten weeks succeeding the outbreak of the epidemic in each city. These ten weeks cover the first and in most places much the more important out-

[2] Full data are available for only 32 cities, but for four cities the weather data for neighboring cities have in some cases been used as indicated by the reference; namely, New York for Newark, Boston for Cambridge, St. Paul for Minneapolis, and Providence for Fall River. The results are practically the same whether 32 or 36 cities are employed.

break. The committee also obtained data as to the temperature, the relative humidity, the absolute humidity and the change of temperature from one day to the next. These weather data were tabulated for periods of ten days beginning 70 days before the onset of the epidemic and continuing 50 days thereafter. The results appear in Table IV where, for convenience, only the ratios between the correlation coefficients and their probable errors are given. A minus sign before the ratio means that the sign of the coefficient is negative, or in other words that when deaths from the epidemic were numerous the indicated weather condition tended to have a low value.

This table is full of interesting facts. Previous to the thirtieth day before the epidemic there is evidence of no strong relationship between any weather condition and the destructiveness of the influenza. During the 30 days just before the onset of the epidemic, however, the temperature and especially the absolute humidity show a strong relation to the succeeding death rate. This means that if the weather was warm during the month before the influenza reached a city, the death rate was high; if the amount of moisture in the air was great, the conditions were still worse. At Boston, for example, from the twentieth to the eleventh days before the epidemic the temperature was higher than during the corresponding period in any other cities except New Orleans, New York and Los Angeles. This was because the epidemic broke out in Boston earlier than anywhere else. In places like St. Paul, Toledo and Grand Rapids, where cool and fairly dry autumn weather prevailed for a month before the epidemic, it apparently gave people a certain degree of stored-up vigor which stood them in good stead and warded off the ravages of the disease. If the temperature was variable, as it was in Cleveland, Columbus and Richmond, and especially if it fell during the ten days after the onset of the epidemic, the death rate was lower than where the contrary conditions prevailed, as appears from the high negative coefficient in column III. On the other hand, high relative humidity and damp air during the ten days before the onset, as appears in Column V, were associated with a relatively high death rate. Cambridge, New Haven and New Orleans suffered most in this respect. Such conditions perhaps made it easy for the bacteria to be transmitted. Droplets of water in the air may act as carriers of the bacteria, or may preserve their virility.

From the tenth to the thirtieth days after the onset of the epidemic the virulence of the bacteria was apparently so great that the state of the weather made no difference in the death rate. The vigor stored up from a previous period of good weather, however,

was clearly of great value, but the immediate weather conditions were not able to overcome the sudden and sweeping character of the infection when once it was started. After the thirtieth day there came another change, and the figures in the columns for temperature and absolute humidity again rise high. This was the time when in most places the disease reached its maximum and began to decline. At that time cool and moderately dry weather once more was associated with a low death rate. This does not necessarily mean that cold weather is favorable at the time of an epidemic. In fact, quite the contrary may be the case, for very low temperature may be as bad as high. Labrador suffered greatly in the epidemic of 1918.

Let us now put all the conditions of weather together, and compare their relation to the epidemic with that of four other factors, namely, climate and the following normal death rates: from all causes, from organic diseases of the heart and from pulmonary tuberculosis. A figure for the weather has been obtained by making the sum of the squares of the departures of the four conditions in Table IV proportional to the square roots of their correlation coefficients with the epidemic during the time when they appear to have been effective. For climate we will use what I have called climatic energy, that is, the degree of activity, vigor and health which any given climate appears to impart. This has been estimated on the basis of the measured work done by factory operatives and students in different kinds of weather. The results of a comparison of each of these five factors with the destructiveness of the influenza, when the remaining factors are held constant and thereby eliminated, are given in Table IV.

TABLE IV

Partial Correlation Coefficients between Death Rate from Influenza and Pneumonia for Ten Weeks in 1918 and Five Variable Conditions which may have had an Effect on that Death Rate

	Coefficient	Ratio of Coefficient to Probable Error
Death rate from tuberculosis	— 0.099	0.9
Death rate from all causes	0.271	2.6
Death rate from heart diseases	0.306	3.0
Climate	0.202	1.9
Weather	0.570	7.6

The meaning of this table is clear. When the factors which have been supposed to cause the influenza to differ in severity from city to city are analyzed according to the method of partial correlations, only one proves to have any unequivocal connection with the matter. That one is the weather. In this particular epidemic the

most fortunate cities were those in which during the month before the onset of the disease and during its crisis the thermometer had fallen fairly low after the heat of summer, but not low enough so that people began to feel cold or to need regular fires in the furnace. Dry air when the bacteria were first spreading and a drop of temperature immediately thereafter seem also to have been helpful. Data from other countries seem to support this conclusion. At any rate, so far as statistics are available, they show that India, Mexico, South Africa and other countries with relatively warm relaxing weather at the time of the epidemic, had enormous death rates from influenza compared with those in the United States; while eastern and southern Europe with their more monotonous weather suffered much more than western Europe. The degree of progress among a people and their regard for the ordinary rules of sanitation doubtless played an important part. But that part is probably smaller in a violent epidemic than in most diseases, as we may judge from the fact that typhoid fever shows no relation to the destructiveness of the epidemic in the United States. All this does not shed light on the perplexing problem of how epidemics arise and how the bacteria can be prevented from attaining the sudden virulence which is the most puzzling factor of all great epidemics. But it does suggest the favorable conditions of the air were the greatest factor yet detected in helping the people of the cities of the United States to ward off the influenza in the fall of 1918.

NATURE AND ART

By Professor I. W. HOWERTH
COLORADO STATE TEACHERS COLLEGE

CORRECT conceptions of nature and art, of their essential characteristics, the difference between them and their relations to each other are the foundation of a sound scientific social philosophy. Such conceptions are plainly necessary to a correct understanding of the function of mind in the cosmos, and to the perception and progressive realization of the possibilities of intelligent action in directing and accelerating the march of social events. I purpose to show, therefore, the scope of the world of nature and the world of art, the real distinction between them and how they are related, and to point out some of the social implications of such distinction and relation.

First, however, as to the meaning of the terms employed.

The word "nature" is used chiefly, of course, in two senses, First, it is employed to denote the sum total of all things. It is thus made to include art. In a well-known passage Shakespeare says,

> Nature is made better by no mean,
> But Nature makes that mean; so, over that Art
> Which, you say, adds to Nature, is an Art
> That Nature makes.

And again,

> . . . . this is an art
> Which does mend nature, change it rather, but
> The art itself is nature.[1]

This, of course, is not the sense in which we shall employ the term.

Secondly, it is often if not usually restricted in its application to the phenomena that are altogether independent of human intelligence, that are due to the operation of purely natural forces and subject only to purely natural laws; as, for instance, volcanic eruptions, earthquakes, storms, floods, ocean currents, tides, winds, cloud movements, the growth of plants and animals in a state of nature, etc., etc. It is in this restricted sense, with certain extensions to be seen later on, that we propose to use the word nature.

The word "art" is also used in more than one sense. In teleological parlance the deity is "The Great Artificer" and "The Author"

[1] "Winter's Tale," Act IV, Sc. 4, lines 89–97.

of all things. "All things were made by him, and without him was not anything made that was made." In this view, "all things are artificial, for nature is the art of God."[2] So the poet, Young, in "Night Thoughts" ("Night" IX, line 1267), declares, "the course of nature is the art of God"; and Pope proclaims, "All nature is but art unknown to thee,"[3] etc.

Again, the word "art" is employed as if it applied only to poetry, painting, music, sculpture, etc, the so-called "fine arts." This is, of course, a purely conventional, not the scientific, sense of the word For it is obvious that it applies also to the handicrafts, the making of things by tools and machines, to agriculture, etc., that is, to the mechanical and industrial arts. Properly speaking, then, art includes all these forms of activity, and it is in this broad and inclusive sense that the word will be employed throughout this discussion.

To appreciate the full scope of art, however, we must note carefully the distinction between art and "the arts," or, preferably, between art and "an art."

An art is a combined and coordinated system of human (artificial) activities continuously pursued and resulting in the production of such commodities or the rendering of such services as may secure for it a social sanction. Obviously, many such activities never become an art. And yet, every art must have its beginning in an artificial phenomenon, and a true definition of art must be broad enough to include every phenomenon of this kind. We have defined it as "the endeavor to realize an idea, ideal or purpose through the conscious employment of means."[4]

Art, then, as we shall employ the term, embraces every form of action involving a conscious purpose and a means of achieving it. Nature and art taken together thus include the entire phenomenal world.

Considering nature, then, in the narrower sense of the word, and art in its broadest sense, what is the true distinction between them?

Professor Huxley suggested the distinction in a general way in a passage which reads:

> In the strict sense of the word "nature," it denotes the sum of the phenomenal world, of that which has been, and is, and will be; and society, like art, is therefore a part of nature. But it is convenient to distinguish those parts of nature in which man plays the part of immediate cause, as some thing apart; and, therefore, society, like art, is usefully to be considered as distinct from nature.[5]

[2] Sir Thomas Browne, "Religio Medici," Pt. XVI.

[3] Essay on Man, EP. I. L. 289.

[4] See "The Art of Education," New York, The Macmillan Co., 1912, p. 2.

[5] Huxley, T. H., "Evolution and Ethics," New York, 1911, p. 202.

But the distinction drawn by Professor Huxley is not, perhaps was not meant to be, altogether accurate. He introduces a third term, society, and writes as if society belonged neither to nature nor to art, whereas it belongs to both. For the purposes of this discussion the distinction must be more clearly stated.

To perceive the distinction between two complexities we reduce them to their simplest terms. To the two now under consideration, if anywhere, we may apply the principle *uno disce omnes.* Let us, then, by examining, first, a simple natural, and then a simple artificial, phenomenon, endeavor to see exactly what differentiates the one from the other. Take, say, the flow of a river through an undeveloped country. All will agree that this is a natural phenomenon. A form of matter, water, moves along in the line of least resistance in obedience to the natural law of gravitation, its course and windings being determined by the general topography of the country and the friction of the river on its bed and banks. Human effort and intelligence have absolutely nothing to do with it; it is purely a phenomenon of nature. Now, let us suppose the water of this river, or a part of it, to be diverted by causing it to pass through a ditch or a flume for the purpose of irrigating a field. We now have the same phenomenon with a difference, the difference consisting wholly in the introduction of a means, the ditch or flume, and a purpose, irrigation. The phenomenon has now become plainly artificial. A means and a purpose, then, added to or mixed with a natural phenomenon make it artificial. That is the sole difference between a natural and an artificial phenomenon, and, as the difference between two such phenomena is the difference between all, we have here the true distinction between nature and art.

So far, the discussion is simple and elementary. But some further illustration may be necessary to make the distinction clear.

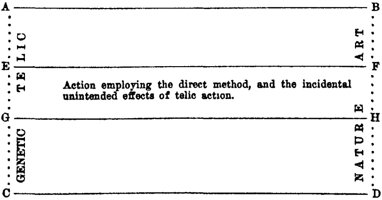
Suppose, then, that water is lifted from the river in the palm of the hand with the object of quenching the thirst. Here is an act involving means (the hand) and a purpose. Is it to be regarded as a part of nature or a part of art? That depends upon where we draw the line with respect to means. It must be arbitrarily drawn, for there are no exact lines of demarcation in this universe of infinitesimal gradations. Let us limit our conception of means, then, to things external to the organism or agent. In the case just cited no means is employed other than nature's means, that is, a part of the organism, the hand. Nothing mediates between the actor and the object, the force is directly applied. It is "direct action," and this direct method of conation is characteristic of nature. This act, then, must be regarded as belonging to nature.

Suppose, again, that in the endeavor to carry water through a ditch or flume in a settled country, some of it escapes and damages

somebody's property. What kind of phenomenon is that? It is a natural phenomenon, for intent or purpose is wanting. It is an incidental effect of purposive action, and belongs to the purely natural as much as if man had nothing whatever to do with it. What of the carrying of sand and gravel and depositing them upon the field to be irrigated? That, also, is a natural phenomenon and for the same reason, namely, the absence of purpose.

Nature, then, includes not only such phenomena as those with which man has nothing to do, but also all those phenomena that are due to his action but in which either of the two elements, means and purpose, is wanting; that is to say, all incidental and unintended results of man's action, and all purposeful actions performed by the direct method of conation. These two classes of phenomena cover a wide field. They include the major part of "social" phenomena.

Nature is self-active, and, as nature as a whole is regarded as a process of becoming, we say that natural phenomena are genetic, from the Greek verb Γεηος, whose root meaning is to become. Art, however, is always telic, (Τελος, end), that is, it is always aimed at something; it is purposive. But, as has just been shown, not all telic or purposive action belongs to art. From art must be excluded, generally speaking, all telic phenomena in which the direct method is employed; that is to say, the achievement of a purpose without the conscious employment of means. In other words the distinction between nature and art is not the same as the distinction between genetic and telic, or as that between nature and man, or nature and society. The exact scope of nature and art and the line of cleavage between them may be roughly suggested by the following figure.



Let the parallelogram A, B, C, D, represent the entire phenomenal world. We may then draw the lines G, H, to separate genetic from telic phenomena, and the line E, F, so as to include within the

rectangle E, F, G, H, those phenomena in which man plays a part, but which are either incidental to his purpose, or, while telic or purposive, are yet performed by the direct method, that is, without the conscious employment of means. The rectangle E, F, C, D, will then cover the realm of Nature, and that of A, B, E, F, the realm of Art. Presented in a diagram the matter will appear as follows:[6]

Phenomena	Natural	Genetic	Spontaneous.
			Incidental to telic action.
		Telic, but employing the direct method of conation.	
	Artificial	Telic, employing the indirect method of conation.	

The figure and diagram are, of course, somewhat misleading, for art and nature can not thus be so neatly separated. They are always found together. For, as Emerson said, while "nature in the common sense applies to essences unchanged by man, space, the air, the river, the leaf; art is applied to the mixture of his will with the same things, as in a house, a canal, a statue, a picture." Thus, art, he says, is "nature passed through the alembic of man."[7] But some such diagram may be an aid to the conceptions we have tried to set forth.

Now, as art always implies a means and a purpose, it is synonymous with intelligent action, and we may safely say that it lies wholly within the realm of conscious human action. Physical nature simulates art to some extent. It utilizes all the mechanical principles, save perhaps the wheel and axle. There are more or less authenticated instances of animal action that simulates art; the use of stones and clubs by some of the higher apes, for instance. The solitary wasp has been observed in the act of tamping the ground over its eggs with a small stone held in its mandibles. Ants, bees, beavers, etc., are said to "ply their arts." All such cases, however, should probably be relegated to instinct, and instinctive action is always a natural phenomenon, since it is action without a conscious purpose. At all events, we shall not be far from the truth if we regard art as belonging wholly to the human realm (not coextensive with it, however), and turn now to consider its true relation to nature.

[6] See Ward, Lester F., "Dynamic Sociology," Vol. II, pp. 103–106. Ward says, "Natural phenomena include all genetic phenomena, and direct teleological phenomena in addition; artificial phenomena coincide and are strictly identical with indirect teleological phenomena," but he does not point out that unintended results of telic action belong with natural phenomena and are subject to the same laws.

[7] Complete Works, Concord Ed., Vol. I, pp. 5, 24.

The prevalent conception as to the relation of nature and art is, perhaps, that they are antagonistic. Primitive men, observing that some natural phenomena were harmful, some helpful, peopled the world with bad spirits and good spirits, which they sought to propitiate. Thus, early arose exorcism, incantation, prayer, sacrifice and the various other forms of religious ceremony addressed to such antagonistic spirits Later, either by an inference from the political organization existing at the time, or from the mental tendency of man to integrate his conceptions, possibly from both, there arose the idea of two great and ruling antagonistic powers or principles operating in the world. Almost all the great religions give evidence of this view. In the Ancient Persian religion, for instance, we find Ahriman the God of Evil, and Ormuzd the God of Good; in the Hindu religion, Vishnu and Siva; in the Egyptian, Osiris and Typhon; and among the Christian nations, God and Satan, and the conception of good and evil principles. Evil is usually attributed to nature, including man's nature. Man, it is said, is prone to evil, "born unto trouble, as the sparks fly upward." By nature he is wayward and sinful. The spiritual man is at war with the carnal, *i.e.*, the natural, man. Conscious moral effort, then, that is art in the field of ethical action, should be constantly directed towards checking man's evil tendencies, that is, to antagonizing nature as manifested in him. Repression thus becomes the object of the moral life. Man arises, civilization advances, in proportion to man's success in opposing nature. This is the prevalent religious view.

Science has done something, too, to encourage this theory of antagonism between nature and art. It has revealed and emphasized the fact that there are, indeed, opposing forces and principles in nature—gravitant and radiant forces, attraction and repulsion, heredity and variation, growth and decay, imitation and invention, etc., and it admits, of course, the existence of good and evil. It has made much, too, of the fact of universal struggle, without which nothing could exist either in nature or in art. For these and like reasons the idea has developed that nature and art are antagonistic.

Curiously enough, this theory of antagonism received its strongest support from one of the greatest of scientific men. I refer, of course, to Professor Huxley who, in his celebrated Romanes lecture entitled "Evolution and Ethics," delivered in Oxford on May 18, 1893, took the ground that the ethical process (art) is directly opposed to the cosmic process (nature). He says:

Social progress means a checking of the cosmic process at every step and the substitution for it of another, which may be called the ethical process. . . . The practice of that which is ethically best—what we call goodness or virtue—

involves a course of conduct which, in all respects, is opposed to that which leads to success in the cosmic struggle for existence. . . . Let us understand, once for all, that the ethical process of society depends, not on imitating the cosmic process, still less in running away from it, but in combating it.

Antagonism, he declares, is everywhere manifest between the artificial and the natural.[8]

All this, of course, amounts practically to the theological view just mentioned, and confirms the prevailing idea of the antagonistic relation of nature and art.

That this theory, however, is incorrect, or at all events misleading, may be shown by considering once more the simple illustration used at the beginning of this discussion with the object of seeing just what takes place in the matter of transforming a natural into an artificial phenomenon. When the water in a river is turned into a prepared channel in order to irrigate a field, the force of gravitation is not combatted, it is merely directed. Such action does not even suggest a combat. Nor do we talk of combating a horse, for instance, when we are merely driving it; and yet the process is practically the same as in the former case. The situation is not different with respect to moral actions, that is to say, in ethics. The cosmic process is not opposed to the ethical process, it is altogether passive and indifferent to it. And so nature and art may not properly be represented as antagonistic. They may appear to be so at first, but close examination shows that this is a delusion. Goethe expresses the correct idea in his poem on "Natur und Kunst." He says:

Natur und Kunst die scheinen sich zu fliehen,
Und haben sich, eh' man es denkt, gefunden.
Der Widerwille ist auch mir entschwunden,
Und beide scheinen gleich mich anzuziehen.

Now, since art, as we have said, is practically limited to the conscious acts of man, we have, in the discussion of the relation of nature and art, necessarily considered the relation of nature and man. If art and nature are in conflict, then it must be that man and nature are in conflict, and this is almost the general view. We speak of "conquering" nature. Life, by ancient philosophers and by the practical men of affairs to-day, is represented as a fight. "To live is to fight," said Seneca. Beaumarchais chose for his motto, "My life is a fight." Goethe said:

Den ich bin ein Mensch gewesen,
Und das heist ein Kämpfer sein.[9]

[8] Huxley, T. H., "Evolution and Ethics," New York, 1911, pp. 13, 81, 82, 83.

[9] This and the immediately foregoing quotations are used by F. G. Nicolai in the "Biology of War," p. 36.

In an address of the late Secretary of the Interior, Franklin K. Lane, he said, "The one fight, the enduring contest, is between man and physical nature." And again, he said, "this world was made for a fighting man and none other." These are but samples of current expressions on this subject. Even followers of the "Prince of Peace" still speak of "fighting the good fight of faith," apply military terms to their leaders, call themselves "soldiers," plan "campaigns," and stimulate themselves by singing hymns of "battle" and shouting peans of "victory." The highest encomium of a man in public life pronounces him a "fighter," and the warrior is still, as heretofore, the beau-ideal of mankind.

All this betrays a singular misapprehension. God and nature are not at strife. No more is art and nature, or man and nature. The function of man with respect to nature is employment or control. And if skilful and ideally effective control of nature's forces, as manifested in the physical, vital, psychic and social world, be taken as the standard, the fighter is a fool, for fighting is the least intelligent of all methods employed in the control of nature.

If it be claimed that the representation of life as a fight is a mere metaphor, then it should still be said that the metaphor is misleading and pernicious, for it tends to excuse and justify the war of man against man, and to evoke the raptures which some profess to feel "over civilized human beings crawling about on the ground and shooting at one another."

But let us glance more closely at the relation of art and nature, limiting our view to simple illustrations. Consider, for instance, the art of invention. Does the relation of the inventor to the force or phenomena he wishes to control suggest antagonism? Does his procedure imply a fight? The very idea is absurd. What he undertakes to do is to fit means to an end, the end being the turning of a natural force, or forces, into channels of human advantage. He studies the forces involved and the materials for controlling them, and selects the appropriate means. It is the same in all the other arts—in agriculture, in legislation and in education—for all the arts are of essentially the same nature.

It is the same, too, in the moral life. Evil is only the result of misdirected impulse, passion and propensity. Man's natural proclivities are really manifestations of vital and mental forces. They are not to be conquered or put down, any more than physical forces are to be conquered or put down. They are only to be controlled or directed to the achievement of worthy ends. Good and evil are alike the result of the operation of natural forces, as much natural as the physical forces. These forces may be controlled and directed. Good and evil are relative terms. One may be turned into the other

by changed circumstances, or by directing the force that gives rise to it into a different channel. Self-control is, therefore, the essence of the moral life.

Concluding this part of the discussion, we may say that man is a product of nature. He is a natural outcome of the cosmic process, that is, of evolution. By virtue of his possession of intelligence he has become a student of nature, and by the application of his intelligence he has in some measure learned to control it. He is, to the extent of his knowledge, its master. But his mastery is not the result of a fight against it. Bacon says that we conquer, that is, master, nature not by opposing but by obeying her, that is, by acting in harmony with her laws. It is foolish to think of fighting nature. She is not to be fought and conquered but to be studied and used. Nature is not opposed either to art or to man.

Every shape and mode of matter lends
Its force to the omnipotence of mind.

There is another theory of the relation of nature and art that deserves at least a passing notice. It is the theory that the whole creation centers in man, the darling of the universe; that not only were all things in nature created for him, but also that there is in nature a beneficent agency operating in the direction of his welfare and advantage; it is the anthropocentric theory.

Although this view is still adhered to by the orthodox in theology, and has been defended in one of its forms by no less a scientific authority than Alfred Russel Wallace, the evolutionary explanation of the various and marvelous adaptations that formerly were regarded as evidence of design in nature, and the numerous dysteleological facts of nature pointed out by Haeckel, Metchnikoff and many others have widely discredited it.

The existence of an active beneficent tendency in nature is negatived by the facts of everyday observation, as well as by the basic principle of all science, namely, the universality and changelessness of law. In a flood, fire, hurricane or earthquake, the natural forces involved are observed to operate on the line of least resistance, no matter what devastation of life and property may result. An authenticated exception to this mode of action would not only destroy the exactitude of science, but would also introduce uncertainty into all the practical affairs of men.

It is strange how long it has taken the world to see that a world of special providence is practically equivalent to a world of chance; that the certitude of science is better than miracles; and that "the best of all possible worlds," considered merely as a theater for artificial action, that is, for the intelligent activities of man, is a world

of fixed and unchanging laws. The only sense in which nature is anthropocentric is that of its potential utilization. It is beneficent only in the sense in which the unused minerals of the earth, uncut timber, unharnessed water power, uncultivated soil, unconfined steam and uncontrolled electricity are beneficent. It is not nature but art that is anthropocentric.

> Strong, simple, silent are the steadfast laws,
> That sway the universe, of none withstood,
> Unconscious of man's outcries or applause,
> Or what man deems his evil or his good.

Nature, then, through all its departments is entirely passive with respect to art. It is amoral. It knows nothing, it cares nothing, for man, that is, for art. Good and bad alike, pleasure and pain, joy and sorrow, are merely the results of the particular relations that man sustains to it. Some look at it and, seeing that it is "red in tooth and claw," cry out against its cruelty. Others, beholding certain beautiful natural adaptations to the needs of man, fall into raptures over the beneficence of nature. But nature is neither cruel nor kind, neither malevolent nor benevolent. It is merely a reservoir of materials and forces which are at the service of man. "Nature," truly said Emerson, "is thoroughly mediate. It is made to serve. It receives the dominion of man as meekly as the ass on which the Savior rode. It offers all its kingdoms to man as the raw material which he may mould into what is useful."[10]

What, then, is the true relation of nature to art? It is the relation of iron to the moulder and manufacturer; of bricks, stone and mortar to the builder; of clay to the potter; of marble to the sculptor; of seed and soil to the farmer; it is the relation of steam to the mechanical and electricity to the electrical engineer; it is the relation of means of effort to the only being in the world capable of conscious achievement. In short, the relation of nature to art is the relation of means to purpose. Nature is the opportunity of art.

Now, glance for a moment at the amplitude and variety of the means provided by nature for the uses of art. We live on a globe, which, though small as compared with some of the other planets, is yet large enough for any purpose thus far conceived by man. It is stocked with a wonderful supply of materials and forces; with metals and other minerals to the number of perhaps a thousand; with millions of forms of plant life; with hundreds of thousands of species of animals. All this vast array of materials in the animal, vegetable and mineral world constitute only man's "visible means of support." In addition there are also the invisible forces of the

[10] *Op. cit.*, p. 40.

physical, vital, psychic and social worlds, which make nature dynamic and creative, which are all subject to the control of intelligence and which, when intelligently directed, may multiply man's power to an inconceivable degree. Truly man's patrimony is marvelous; he lives in a wonderful world.

> The hills,
> Rock-ribbed and ancient as the sun. The vales
> Stretching in pensive quietness between;
> The venerable woods, rivers that move
> In majesty, and the complaining brooks,
> That make the meadows green, and poured round all,
> Old ocean's gray and melancholy waste,—
> Are but the solemn decorations all
> Of the great (Home) of man.

Now, observe the comparatively slight degree in which man has thus far employed the materials and forces that are ready to his hands. Gold, silver, copper, iron, tin, lead and mercury have been known and used since the beginning of history. Glass, a fused combination of the silicates of sodium and calcium, or of potassium and calcium, was employed for useful or ornamental purposes by the ancients. Many other elements and compounds have been brought into common use. But, of the 80 or more chemical elements, half were undiscovered at the beginning of the last century. How many more are yet to be discovered we do not know. Radium, only recently found, is certainly the most curious and may yet prove to be the most useful of all. Elements supposed to be of no use, like lanthanium and neodynium, have been found to be in some of their compounds of inestimable service. Creative chemistry, inorganic and organic, is in its infancy. We have about a thousand mineral species. The inorganic compounds artificially formed from them number about 10,000, but the possible combinations are infinite. Organic compounds are said to number about 100,000, but here, too, the possibilities are infinite. We have already attained the artificial production of many of our foodstuffs, including an artificial substitute for sugar, only albumen remaining to be synthesized. The forces of gravity, steam, heat, light and electricity are used, but only to a very limited extent. The water power of the world, to say nothing of electricity and the other great physical forces, many no doubt undiscovered, is sufficient to do all its work, and more. The direct exploitation of solar energy, certainly possible, would render the earth habitable to many billions more people than it now contains.

From the vegetable world we derive food, clothing, shelter, ornaments, etc., drugs, balsams, resins, gums, dyes, oils, perfumes, spices,

etc., etc., but most plants are yet unemployed, those used are too often destroyed and only recently have we begun to create new forms of plant life, the possibilities in this direction being also infinite.

Of animals we have domesticated a few, utilized the skins and flesh of many, and utterly destroyed some which, if preserved, might have added immeasurably to the support, convenience and esthetic enjoyment of life. The passenger pigeon, for instance, innumerable within the memory of men now living, is as extinct as the dodo. The buffalo is a curiosity. Our game birds and beasts are rapidly disappearing. The "pot-hunter," so far from being conscious of his true significance in a world economy, or from being ashamed of the part he is playing in it, enjoys having his picture taken surrounded by the evidences of his "prowess!"

Two things, then, are clear: First, man has scarcely made a beginning in the employment of the materials and the forces of nature, nature being for the most part wild, untamed, unused; secondly, his use of these materials and forces is largely abuse.

To be sure, man prides himself on what he has achieved in the sciences and the arts. It is much in comparison with nothing, but almost nothing in comparison with what may be done. The physical sciences have rapidly advanced during the past three centuries because the world has been blessed with a few men who loved truth for its own sake and pursued it in spite of all opposition; but particularly because the physical arts derived from them have lent themselves to the immediate and practical purposes of men who knew how to use them in the pursuit of their own ends. The biological sciences have made great strides since Darwin, and a beginning has been made in the arts of cultivation and of breeding. Psychology until recently was a pseudo-science, and the corresponding arts of education and individual and institutional management are still largely empirical. But the great science of society is yet struggling for recognition, and the art of social control, of social self-direction, of orderly progress, is but faintly manifested in a few sporadic attempts at social legislation. We are indeed "in the stone age of politics." Society as a whole has not begun to look after its own interests. It is not Man that is intelligent, but men. Mankind as a whole has yet to develop a unity of purpose and an organization of effort which alone can enable it to utilize the materials and forces of nature in the promotion of its own progress, and thus build the society of which some have dared to dream. As to the abuses of nature, Alfred Russel Wallace has so well expressed the facts and their significance that I will quote his words. After dwelling upon the marvelous variety of the useful and beautiful

products of nature, and how this variety and beauty, even their strangeness and ugliness, excite in us admiration, wonder and curiosity, the emotions at the basis of observation and experiment and therefore of all science and philosophy, he says:

> These considerations should lead us to look upon all the works of nature, animate or inanimate, as invested with a certain sanctity, to be *used* by us but not *abused*, and never to be recklessly destroyed or effaced. To pollute a spring or a river, to exterminate a bird or beast, should be treated as moral offences and as social crimes. Yet during the past century, which has seen those great advances in the *knowledge* of Nature of which we are so proud, there has been no corresponding development of a love or reverence for her works; so that never *before* has there been such widespread ravage of the earth's surface by destruction of native vegetation and with it of much animal life, and such wholesale defacement of the earth by mineral workings and by pouring into our streams and rivers the refuse of manufactories and of cities; and this has been done by all the greatest nations claiming the first place of civilization and religion. And what is worse, the greatest part of this waste and devastation has been and is being carried on, not for any good or worthy purpose, but in the interest of personal greed and avarice; so that in every case, while wealth has increased in the hands of a few, millions are still living without the bare necessaries for a healthy or a decent life, thousands dying yearly of actual starvation, and other thousands being slowly or suddenly destroyed by hideous diseases or accidents directly caused in this cruel race for wealth, and in almost every case easily preventable. Yet they are not prevented, solely because to do so would somewhat diminish the profits of the capitalists and legislators who are directly responsible for this almost world-wide defacement and destruction and virtual massacre of the ignorant and defenceless workers.[11]

Here, then, in brief, is the situation presented by an impartial study of nature and art: a race of intelligent beings dwelling in the midst of a wonderful supply of materials and forces, all susceptible of use through knowledge; materials and forces so abundant and varied that by means of them the lot of man may not only be somewhat "ameliorated," but improved beyond the dreams of poet or seer.

> The men of earth have here the stuff
> Of paradise, we have enough.
> We need no other stones to build
> The temple of the unfulfilled—
> No other ivory for the doors—
> No other marble for the floors—
> No other cedar for the beam
> And dome of man's eternal dream.

And yet, here are these intelligent beings abusing nature, and destroying through ignorance and greed many irreplaceable means

[11] "The World of Life," Moffatt, Yard & Co., New York, 1916, pp. 300–301.

of human welfare; working at cross-purposes, quarreling and fighting, using the societal organizations, that have come into existence largely through accident, to defeat and destroy each other; glorying in "the pomp and circumstance of war," not sufficiently developed to be ashamed of it; failing to unite in the achievement of a world purpose when presented with a unique opportunity to do so; shouting "patriotism" and failing to perceive that the highest virtue of patriotism is in its mediation to cosmopolitanism, and that man's true Fatherland is not a country but the globe, and now and then gravely marching to temples of worship to beseech the Lord to do for them what they might easily do for themselves. No wonder the Flood!

The situation, however, is not without elements of hope. Men, seeking their own advantage, have demonstrated the enormous possibilities of utilizing the materials and forces of nature as means of promoting the welfare of the individual. None denies that nature may so be increasingly utilized. There is no end to such utilization short of the complete artificialization of nature. "Art," said Emerson, "must be carried out and upward into the kingdom of nature and destroy its separate and contrasted existence. Nothing less than the creation of man and nature is the end of art."

Now, it is an easy inference that what an individual can do and is doing for himself a collection of individuals, that is, society, may do and ought to do for itself. Society is a domain of natural forces. Its progress thus far has been largely a natural process—a result of natural selection, an incidental and unintended outcome of activities of men which though telic were only so from the standpoint of the individual. Society is a unity, a "collective being." How, then, can it be denied that society may and ought to utilize nature after the manner in which the individual has set the example? The process in each case is essentially the same.

To exercise control over nature but two things are necessary, the will and the knowledge. The knowledge that it can be done evokes the will, so that we have only to provide ourselves with the former and the latter will take care of itself. "As we understand nature better," says Ritchie, "and as we understand human nature better, we can secure adaptation and adjustment by bending nature in many ways to ourselves instead of bending ourselves in every respect to nature."[12]

Knowledge is power. Knowledge of the materials and forces of nature, of all nature—physical, vital, psychic and social—is the power to control nature. Knowledge, therefore, is the sole desideratum.

Of course, such knowledge implies imagination and idealistic

12 Ritchie, D. G., "Natural Rights," p. 112.

construction of the ends we wish to serve. The moment we undertake to use our knowledge, to exercise any control over nature, we must have some purpose, some end in view, and if the end is a conception of improved individual or social life, it is an ideal. As already seen, there can be no art without a purpose, but a purpose is essentially an ideal. We can not understand, then, the idea that the formation of ideals is an illegitimate procedure in science. Professor W. G. Sumner says:

> Men who rank as strong thinkers put forward ideals as useful things in thought and effort. Every ideal is a phantasm; it is formed by giving up one's hold on reality and taking a flight in the realm of fiction. When an ideal has been formed in the imagination the attempt is made to spring and realize it. The whole process seems to be open to question; it is unreal and unscientific; it is the same process as that by which Utopias are formed in regard to social states, and contains the same fallacies; it is not a legitimate mental exercise. There is never any correct process by which we can realize an ideal. . . . What we need to practice, on the contrary, is to know with the greatest exactitude, what is, and then plan to deal with the case as it is by the most approved means.[13]

Exactly so, but how, or why "deal with the case as it is," unless to some end? Professor Sumner's proposal is inconsistent with his doctrine. Why should every ideal be a phantasm? Why may it not be a scientific construction on the basis of facts? All that we contend for is that society should find out "with the greatest exactitude" its present conditions and possibilities and then "plan to deal with the case as it is by the most approved means," and that necessitates a social ideal. Mere idealistic speculation is, we admit, an idle pastime. But ideals, social as well as individual, may be constructed on the basis of scientific facts and tendencies, and so determined they are the practical ends of the control by art over nature.

If there are no limits to knowledge, and this is usually regarded as the true view, then there is no limit to the power of knowledge or of art, that is, to what man equipped with knowledge can do. As the field of knowledge is the whole universe of phenomena, cosmic, organic, psychic and social, so the possibilities of control are unlimited in scope. Already the material forces have in large part been brought under the dominion of man; in a lesser but still in large part the vital forces have been brought under his direction; in a yet lesser degree, because man possesses less knowledge in this field, the social forces have also been turned towards the production of improved social conditions. Little has yet been done, because little is yet known in this field. But, given the necessary knowledge

[13] Sumner, W. G., "Earth, Hunger and other Essays," New Haven, 1913, pp. 25-26.

of social relations, who will dare to set a limit to the achievements of art, that is to say, of man, in the matter of realizing here on earth the "kingdom of heaven"? Of old it was said of man that his Creator gave him universal dominion. "Thou madest him to have dominion over the works of thy hands; thou hast put all things under his feet." Science confirms this declaration, only this dominion must be won by the pursuit of knowledge and the exercise of art. And so we may say, as Professor Huxley said, we "see no limit to the extent to which intelligence and will, guided by sound principles and investigations, and organized in common effort, may modify the conditions of existence for a period longer than that now covered by history."[14] He meant, of course, that period when in the course of cosmic evolution the world is to become a dead world because of the dying heat of the sun. But that period is so remote as to give us no concern.

The human race is supposed to have existed between 200,000 and 300,000 years, let us say one quarter of one million years. It has been conscious of its existence only about 10,000 years, and really alive as a psychic being less than 5,000 years. The most it has accomplished of any value to itself has been done within 2,000 years, and its great work within 200 years. In a word, relatively speaking, man has only just begun to exist. His golden age, as Saint Simon said, is before him and not behind him. His history is but the threshold of the Psychozoic age. The whole of that immense period lies before him. The conditions of existence on this earth are now at their optimum, abundance of air and water, heat and light, great variety of surface, soil, climate, mineral resources and all the materials and forces of nature ready to yield to the magic wand of science. There are no indications that these conditions will change in an entire geological epoch. These favorable conditions are certainly liable to last as long as the Tertiary period just closed has lasted, viz., 3,000,000 years. They may continue during the first half of the Psychozoic period of Mars, or 12,000,000 years. And what does a million years mean? Contrast (the human) period with any full geologic epoch and reflect upon its significance. For us the Psychozoic age, or any considerable part of it, means *eternity*.[15]

Now, given the three factors—practically an eternity of time, an almost infinite amount of utilizable materials and forces and a race endowed with intelligence capable of practically infinite development—and the possible progressive realization of a condition of society corresponding to, or surpassing, the loftiest dreams of the poets, is indisputable. James Russell Lowell, to mention but one of the dreamers, declared, in his "Ode to France," that

[14] *Op. cit.*, p. 85.

[15] Ward, Lester F., "Glimpses of the Cosmos," Vol. VI, New York, 1918, p. 258.

Down the happy future runs a flood
    Of prophesying light;
It shows an earth no longer stained with blood,
Blossom and fruit where now we see the bud
Of Brotherhood and Right.

And in another poem, "Elegy on the Death of Dr. Channing," he said that

From off the starry mountain peak of song,
Thy spirit shows me, in the coming time,
An earth unwithered by the foot of wrong,
A race revering its own soul sublime.

But what we have tried to indicate, and in a way to prove, is that from the none too lofty peak of present knowledge, fact and achievement, and through the dry light of science, the same ideal is visible, not as a poetic fancy, not as a delusive mirage that vanishes as we look, but as a possible future condition of society if men will but unite and apply art to the general improvement of mankind. Obviously, there will be no general unity of purpose until through a new education the social possibilities of unified and intelligent effort begin generally to appear. But in him who glimpses these possibilities and perceives that they are based upon scientific facts and laws, there is awakened an enthusiasm for ordered social progress and a sense of duty that are essentially religious. The religion of orthodoxy is fast losing its hold. Many of the religious beliefs drawn from the limited knowledge and active imagination of primitive man are destined to disappear. But here, in a purely scientific view of nature and of art, and of the relation of intelligent man to the world of nature, and the social possibilities that grow out of such relation, are the elements which might be made the basis of "a new religion," the religion of science, the religion of humanity, a religion which of itself should be satisfying to the truly emancipated soul.

MATHEMATICS AS A CAREER

By Professor C. J. KEYSER
COLUMBIA UNIVERSITY

THE aim of this article is to help college and university students having a bent for mathematics to answer some of the questions they ought to consider before deciding whether or not to devote their lives to this field of science.

The questions to be considered may be taken up under the following four heads: "Interest and Ability," "The Nature, Scope, Vitality (or Progressiveness) and Dignity of Mathematics," "The Period of Preparation," "The Mathematician's Rewards."

INTEREST AND ABILITY

In speaking of mathematical ability I shall mean *native* mathematical ability, in accord with the proper sense of the familiar saying that the mathematician is *born*, not made. Every one knows that mathematical ability and interest in mathematical study often go together. And it is commonly believed that the two things are always associated in such a way that intensity of interest implies a high degree of ability, and that superior ability implies corresponding interest (actual or potential). But that belief is erroneous. Every experienced teacher of mathematics knows very well that a student whose mathematical ability is meagre may yet feel and manifest a lively interest in mathematical studies. On the other hand, it occasionally happens that a student having indubitably great mathematical gifts has relatively slight interest in the subject. What I have said of mathematics is equally true of every other form or field of activity.

It is thus evident that what may for a time seem to a student to be an inner summons to mathematics or another subject may or may not be a genuine call thereto. Such a summons requires to be scrutinized carefully, for the choice of a vocation is a momentous act. I do not mean that choice should be deferred in the hope of resolving all doubt, for in such matters complete elimination of uncertainties is impossible. Yet one must decide or drift. But, although the decision must be adventurous, the adventure need not be rash: it may await, not certainty, but the weighing of probabilities.

I believe it safe to say that, with very rare exceptions, a student may not wisely choose mathematics for a vocation unless he has

asked, with respect to himself, and has been able to answer affirmatively, the following questions: Is my seeming interest in mathematics genuine? Is it an abiding interest? Does it exceed my interest in every other subject? Is it deep and strong enough to stimulate my powers to their highest possible activity and cause mathematical work to be for me, not irksome toil, but a labor of love? Have I sufficient mathematical ability to read a solid mathematical work with fair facility and good understanding? Does my mathematical ability exceed my natural ability in every other subject? Do I possess in fair measure the natural gifts essential to the qualifications of a successful teacher of high-school pupils or college students or university undergraduates?

Of the foregoing questions the first one is intended to guard the student against the danger of mistaking for interest in mathematics such transitory delights as a bright student is likely to have in class-room competitions under the quickening influence of a live teacher. If a student have genuine interest in the subject, he will know it; but if his "interest" be spurious, he may be deceived.

The last one of the questions appears to be justified in view of the fact that in our country young men aspiring to a career in mathematics have seldom been able to escape the necessity, even when they have desired to do so, of giving a good deal of their time and energy to the work of undergraduate instruction, and that relief from such necessity does not seem probable.

Ordinarily, a student may not hope to arrive at trustworthy affirmative answers before his studies have advanced far enough at least to include substantial courses in analytical geometry and the calculus. In any case he should seek the counsel of his instructors, especially if they be candid men of mathematical reputation and good judgment.

A more difficult problem presents itself in the case of those rare students who have no decisive predilection for a single subject but have talents and interests qualifying them well and equally for adventure in any one of two or more great fields. It is a pity that such a student can not wisely make it his vocation to cultivate all the fields at once or in succession. There is always something tragic in having to specialize, for in a profound sense the subject of all science is one whole. But the whole is too vast and complicated for the limited powers of one man; whence the necessity for division and for concentration upon a fragment—a necessity whose tragic quality is felt with special keenness by a student of diversified gifts and interests. The fields in question may be or seem to be widely sundered, as geology and linguistics, for example; or they may be obviously adjacent, closely related, interpenetrating, as physics and

chemistry, for example, or zoology and botany, or philosophy and mathematics. If the fields be intimately related a student of the mentioned type may aim at a career in two or more of them combined *provided* he be endowed with a measure of genius like that of Helmholtz, for example, or Henri Poincaré, who won eminent distinction in astronomy, in physics and in mathematics. But men of such capabilities are exceedingly rare. Ordinarily, a student whose tastes and talents qualify him well and equally for two or more important subjects ought to choose one of them definitely and resolutely as a *vocation*, reserving the others not less definitely and resolutely as *avocations;* for ordinarily such a decision will be most favorable to health and happiness, to depth and breadth of culture, to good citizenship in the commonwealth of science, and to the service of mankind.

Mathematical Research Ability and its Test

I have thus far said nothing about research, having reserved it for special consideration because of its grave importance. There is hardly another term so often heard in university circles and no other is mentioned with quite so much respect. Indeed, one sometimes gains the impression that scientific men, or some of them, regard research as being, in comparison with all other activity, not only awe-inspiring but sacred or holy, almost divine. Not infrequently men speak of it with a solemnity like that of a sinner recommending virtue and righteousness, and doubtless they sometimes do it from similar motives, conscious or unconscious.

What does the term mean? In current use it has two meanings, differing in respect to dignity, a minor meaning and a major one. In mathematics the minor meaning of the term research covers a large variety of work which, though valuable, involving something of the spirit and art of discovery and adding somewhat to the body of mathematical knowledge, yet requires neither creative genius nor a *very* high order of talent. I refer to such work as that of effecting improvements in the exposition of classical doctrines; the discovery of new theorems of ordinary difficulty, interest and importance; new demonstrations of important old theorems; the invention of new but subordinate methods; the detection and correction of imperfections in established theories; and so on. Much of the matter found in journals devoted to what is called research is of the sort I have indicated. Of course, it does not represent research in its major sense.

The major meaning of the term, mathematical research, is clearly revealed and rightly represented by nothing save the great achievements of creative mathematicians. Such creative activity

assumes various forms. It may show itself in the discovery of a powerful *method,* like the analytical geometry of Descartes and Fermat or the calculus of Newton and Leibnitz; it may show itself in the creation of a great *doctrine,* like the projective geometry of Desargues and Poncelet or the function-theory of the complex variable (Cauchy, Riemann, Weierstrass); it may show itself in the form of historical research, as in the monumental *Geschichte der Mathematik* of Moritz Cantor; it may show itself in the form of contributions to the logical foundations of the science, as in the *Principia* of Whitehead and Russell or the *Tractatus* of Wittgenstein; it may show itself in the *applications* of mathematics to empirical science, as in the Einstein Theory of Relativity or the Quantum Theory of Planck.

Is it possible for a student to ascertain with a good degree of certainty whether, in the event of his choosing mathematics for a vocation, he may confidently aspire to a research career in the subject? Yes and no. If he can answer affirmatively the foregoing test questions respecting interest and ability, then he may, I believe, fairly assume that his powers are adequate for research in the minor meaning of the term; but with respect to the major meaning no such guaranty is possible. Just here the element of adventure, which choice always involves, is seen at its maximum. For there can be no conclusive evidence of having the power to do great things except achievement.

THE NATURE, SCOPE, VITALITY AND DIGNITY OF MATHEMATICS

The nature of mathematics: A competent student of mathematics whose studies have not advanced beyond a solid year of calculus will not know profoundly or critically what mathematics essentially and distinctively is but he will have felt its appeal and gained some sense of its power. In this brief essay not much can be said regarding the essential nature of mathematics. I venture to refer such students as may be interested in that great question to my "Mathematical Philosophy,"[1] where a serious attempt has been made to set the matter in clear light and where they may find a clue to the literature. Here I can barely touch the subject and must content myself with making a few careful, though unargued, statements having for their principal aim to discriminate justly and clearly between mathematics and natural science.

Natural science employs logic as an instrument, a tool. But to speak of logic as a tool of mathematics is meaningless. Logic is not a tool of mathematics—logic *is* mathematics. All strictly mathematical propositions are propositions of logic, and conversely. But

[1] E. P. Dutton and Company, New York.

no propositions of natural science are propositions of logic, or mathematics, though the latter propositions are such that the best of the former can not be established without them.

Mathematical propositions are true *unconditionally*—which means that their validity is independent of the facts investigated by natural science. But propositions of natural science are only true *conditionally*—on condition, that is, of their agreement with the possible facts asserted by them. Suppose, for example, that p and q are propositions of natural science. The mathematical proposition—if p is true and p implies q, q is true—is true no matter whether p or q or p' implies q' is true or false.

All propositions of natural science are *empirical*, which means that, if a proposition of natural science be true, knowledge that it is true can not be gained by inspecting the meanings of the proposition's terms but rests ultimately upon sense-perception—upon external observation—upon comparison of the proposition with the fact asserted by it. *No* mathematical proposition is *empirical;* knowledge that a mathematical proposition is true can not be gained by sense-perception—by comparison of the proposition with any fact or facts of the external world; the evidence of its truth is wholly contained in the meanings of its terms; and knowledge of its truth results from analyzing those meanings. The processes of what is called mathematical proof are nothing but the processes of such analysis.

Mathematics is silent respecting the empirical realities of life and the world, Yet it is infinitely important as a means for our dealing with them effectively. For it is mathematical propositions, and only they, which enable us to advance by *inference* from given propositions which do relate to empirical realities to new propositions relating to them. Without the process of such *inference,* made possible by mathematics, natural science, even civilization itself, would be impossible.

The scope, vitality and dignity of mathematics: No student need hesitate to choose mathematics for his vocation because of any fear that this subject, when compared with others, may be found to be inferior to some of them in scope, or in vitality and progressiveness, or in dignity.

Consider the question of scope. We know that the world of empirical reality—the subject of Natural Science—is so vast and complicated that each of the natural sciences has for its scope but one aspect or fragment of the world. But we do not know whether the facts composing the world of empirical reality do or do not constitute an infinite multitude; and so we can not assert that the answers, if we had them, to all the questions that all the natural

sciences combined might ask would constitute an infinitude of propositions. With respect, however, to non-empirical truth, with respect to facts of logic, with respect, that is, to propositions that are unconditionally true, the situation is different: we know, from the internal evidence of the case, that mathematical propositions, known and unknown, together constitute, not merely a vast multitude, but an infinite one. Even the body of *known* mathematical propositions is so large that, as I have elsewhere[2] said, "no man, though he have the wide-reaching arms of a Henri Poincaré, can contrive to embrace them all."

With respect to vitality and progressiveness it may be confidently said that mathematics is not surpassed by any branch of science. Its developments in our day proceed so rapidly and in so many directions that the ablest men, being unable to follow all the developments, are obliged to specialize within the general field. Ours is indeed the golden age of mathematics. Not less than eight international congresses of mathematicians were held prior to the World War. More than 500 scientific journals are devoted in part, and more than two score others are devoted exclusively, to mathematical publication. As many as 2,000 mathematical books and memoirs drop from the press in a single year. In all of the great culture nations are found flourishing mathematical societies. The American Mathematical Society, which is primarily devoted to research, and publishes two journals, has about one thousand members. The membership of the Mathematical Association of America, which publishes one journal, is still larger. And in our country, as in others, there are numerous organizations aiming at improvement in the teaching of elementary mathematics.

Nor is the activity thus indicated confined to "pure mathematics." "Applied mathematics" is not less alive. And here I must say a word about those two terms. It is customary to speak of mathematics, of pure mathematics, and of applied mathematics, as if the first were a *genus* owning the other two as *species*. The custom is unfortunate because it is misleading. "Pure mathematics" is a superfluous term, for it simply means mathematics and nothing else. The term "applied mathematics," which came into use before the essential nature of mathematics had been discovered, is a misnomer. The uses or applications of mathematics no more constitute a species of mathematics than the uses or applications of a spade constitute a species of spade.

Of present-uay activity in applications of mathematics to questions of empirical science the tokens are numerous and striking. It will be sufficient to refer to two of them, mentioned before—I mean

[2] "Mathematical Philosophy," p. 21.

the Relativity theories, of which every one has heard, and the not less significant Quantum theories of Planck and others. These two examples have special value on another account. For they teach a most important lesson which it is very hard for the world to learn and they show at the same time how silly it is to debate whether devotion to mathematics or devotion to its applications is the better form of scientific service. The lesson is that a mathematical theory, however abstract and seemingly "useless," will sooner or later get applied to problems of empirical science. For example, the mathematical theory of probability, which had its origin in common games of chance, to-day plays a fundamental rôle in Quantum theory and the kinetic theory of gases. Again, nothing could appeal less to a born utilitarian than the frightfully abstract and complicate Theory of Tensors constructed long ago by Riemann and Christoffel. Yesterday, however, that idle theory became the "backbone" of the General Theory of Relativity. A similar tale could be told of many other mathematical theories long pooh-poohed as idle curiosities, non-Euclidean geometries, for example, and the doctrines of hyperspaces. It is not only astronomy and physics and chemistry that are open to the invasion of mathematical students with a bent for applications but philosophy and psychology, botany and zoology, statistics and economics, and every variety of engineering.

In view of the foregoing considerations it would be superfluous to inquire concerning the relative dignity of mathematics in the general assembly of sciences and arts. Students desiring to inform themselves in respect to the esteem in which mathematics has been held from time immemorial by eminent men and women representing all fields of intellectual and spiritual activity may be referred to Professor Moritz's superb "Memorabilia Mathematica."

The Period of Preparation

What is to be said under this caption with reference to mathematics applies quite as well to every other cardinal subject. The period of preparation usually includes two or three years of university residence devoted to what is called graduate study subsequent to graduation from college. During these years the student will be in fact, if not officially, a candidate for the degree of doctor of philosophy, and his period of preparation for a scientific career will usually terminate when he has gained the degree. To gain the degree he must produce a dissertation embodying the result of fairly independent and somewhat original work and must pass an examination, which may be oral or written or both, in the general field (or fields) of his studies.

The gaining of the doctorate is not regarded as conclusive evi-

dence that the student has research ability in the major meaning of the term as above explained. It is regarded, and rightly regarded, as signifying that the student has attained a fairly high degree of scholarly competence in his field of study and that he possesses research ability in at least the minor meaning of the term. On this account the fact of having won the doctorate is distinctly helpful, and in some instances is even essential, in obtaining a position, especially a college or university appointment, and thereafter in obtaining promotion. It is true that not all doctors of philosophy are scientifically productive; on the other hand, some of the most productive scholars within and without the universities have not held the doctorate; it is also true that pursuit of scholarship and pursuit of a degree, though they are compatible, are not the same. Nevertheless, in view of the prevailing practice, a student aspiring to a university career in mathematics or another subject will find it advantageous to make whatever sacrifice may be necessary for gaining the doctorate

The Mathematician's Rewards

First, a word respecting material rewards Having gained the doctorate, the young mathematician can readily obtain a college or university instructorship at an initial salary of perhaps \$2,000. He will instruct undergraduates and may be permitted to offer a graduate course. If he be a successful teacher and especially if, in addition to that, he wins fair repute for research work, he may confidently expect advancement, in three to five years, to an assistant professorship with a salary of \$3,000 to \$4,000, and, in ten to fifteen years, to the rank of full professor with a salary of \$4,000 to \$6,000 A few men of long service and scientific eminence receive as much as \$8,000 to \$10,000. The material rewards of the mathematician are notably inferior to those of some of his university colleagues, in law, for example, in medicine, and in engineering, for these, in addition to their professorial salaries, often receive incomes, sometimes large incomes, from outside practice of their professions—professions whose service, though it is not superior to that rendered by the mathematician, is more obvious to the indiscriminating multitude, called the public. But the genuine devotee of science is not disheartened by the spectacle of such *iniquity*. He is content with such an income as enables him to support his family decently and to do the work to which he has been summoned by the inner call of his talents

The life-work of the mathematician is richly compensated; but the compensations are not material—they are spiritual. One of them is the joy of life-long contact and intimate association with

the eager minds of the young. Another is life-long companionship with men devoted to science and other fields of scholarship. Another is the privilege of long summer vacations affording special opportunities for study, research, writing and travel. The mathematician's subject is an honored one and his life is a life of perpetual contact with fundamental thought He knows that his science is the science of eternal verities and that its service is essential alike to the prosperous conduct of ordinary human affairs, to the advancement of science and to the support and progress of civilization And, though he can not gain material wealth, his work, if he be a man of genius, may bring him fame—"the lofty lucre of renown"

CONSERVATION AD ABSURDUM

By Professor FRANK A. WAUGH
MASSACHUSETTS AGRICULTURAL COLLEGE

THE constitution of the State of New York explicitly and absurdly provides that "the forest preserve . . . and the timber thereon shall not be sold, removed or destroyed." This is such a picturesque example of a good idea gone wrong that it ought to be framed and hung in all schoolrooms for pupils to study.

The good idea which went wrong was formerly very popular in those same schoolrooms. Boys and girls who spoke pieces on Fridays often recited "Woodman, spare that tree!" The woodman very seldom heard or heeded, but the idea, in other company, was growing and fructifying into the early doctrine of conservation. One great trouble of the present is that there are millions of honest citizens who have taken only the first degree in conservation, a degree in which the password is still, "Woodman, spare that chestnut."

Meanwhile the conservation lodge has grown in adherents and progressed in its ideas. George Pope Morris with his old password could not now get beyond the outer gate. Modern conservation was chartered and constitutioned by Theodore Roosevelt and Gifford Pinchot, and while the very first article in their constitution called for the preservation of American forests, the whole argument was pro-woodman, not anti-woodman. It was clearly recognized that in a civilized land the ax was the natural destiny of the forest.

To put the matter differently and better, it was proclaimed that conservation was not an end but a means. The end is utilization for the benefit of humanity. All nature's gifts—forests, fish, soil, human life—should be cherished, cultivated, protected and *used.* The fullest and highest use can be reached only after judicious saving and careful cultivation have made the most of each resource; and then the state is under obligation to transmit all these resources undiminished to posterity.

Every one of our natural resources comes under the laws of conservation. These laws may be codified in five principal chapters, *viz*:

1. Saving
2. Cultivation
3. Improvement
4. Perpetuation
5. Utilization

Apply these laws to the forests just for illustration.

First, the forest lands must be saved. They have to be rescued sometimes from the ungodly woodman admonished in Mr. Morris's poem; but oftener they have to be saved from fire. The great problem of forest conservation, especially in America, is fire protection. In other cases, too, our American forests had to be saved from over-grazing.

Second comes cultivation. The forest is a crop and requires attention like a crop of potatoes, except that different methods are used. Here we have the whole science and technic of sylviculture, one of the main branches of forest practice as taught in all the schools.

Thirdly, the forests ought to be improved. Good timber stands should succeed cut-over and waste areas; better species should follow poorer. Just as the farmer strives always toward crop improvement and just as the cattleman is forever trying to breed better stock, so the forester is not satisfied to cultivate his current crop but must always be seeking something better.

Fourthly, stands the vital problem of perpetuation. No forest will stand forever. Even the big sequoias will die some time. Our greatest worry over the millions of acres of cut-over, burnt-over land in America is not that the standing timber is gone but that no provision is made for a renewal of the forest. The great and favorite sin of our generation consists in robbing future generations. We use what should belong to them and we make no provision to replace what we steal.

Lastly and most importantly comes utilization. There is absolutely no sense in saving forests if they are of no use. Here is where the public mind needs a lot of clarification.

Of course any forest in being has some use, perhaps highly valuable uses. It protects a city's water supply or it offers recreation to millions. It is by no means necessary to chop down all the trees in order to use a forest.

On the other hand, it is equally unnecessary to leave every tree to die and rot on the ground. The simplest and best procedure is to remove each tree when it is mature. Under good management its place will then be taken by a younger tree, and so, by this system, the forest is always made up of young vigorous growing trees, whereas by the other system, required under the constitution of the state of New York, the forest must always contain a considerable percentage of decrepit, diseased, shattered, dead and rotting members. These dead, down and rotting trees add nothing to the beauty of the woodland. If the human soul really delighted in such forestry then would we make our parks on that formula and our home

A TRAIL ON MT TOBY, MASSACHUSETTS AGRICULTURAL COLLEGE DEMONSTRATION FOREST

grounds would be embellished with blasted and decaying specimens. This dead and down material also increases the fire hazard. From every standpoint, in short, it is a detriment to the forest and useless to mankind. Yet that is what the constitution calls for.

Once the absurdity of this idea is seen it readily follows that when mature trees are removed for the good of the forest the lumber may be turned to human use without further injury to the sacred cause of conservation. In short there may be established a system of forestry in which woodlands are saved, cultivated, improved and perpetuated while the timber is also used—all of it. This is so simple that it hardly required to be stated. At least it would not, except for the contrary doctrine laughing at us in the Constitution, Art. VII, Sec 7

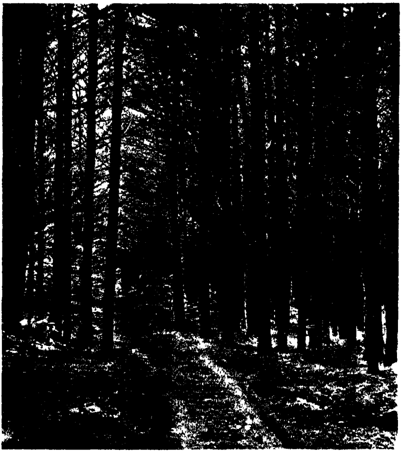
Wild as it is, this conflict of ideas is easily explained. It arose from the confusion in the public mind of American lumbering with scientific forestry. American methods of exploitation have of course devastated millions on millions of acres of fair and noble woodland with seldom a thought to any future. And so Mr Morris, who wrote the poem, and Messrs New York State and Co, who wrote the constitution, got the idea that forestry was all like that. They wanted "conservation with teeth in it." They were determined that the woodman should spare that tree, even if it did have to rot on the land. Mr. Morris said so with poetry; but the constitutional convention missed both the rhyme and the underlying facts

Yet one should not rail too roundly upon the constitution nor the men who made it. There are millions of men and women with equal qualifications of ignorance who have never yet been elected to the legislature nor to a constitutional convention, but who in their more influential positions as presidents of woman's clubs, parish priests, family doctors, principals of schools and trolley car conductors, are spreading the same preposterous notion of conservation. One meets it everywhere The foresters in charge of state and national forests probably hear from it oftenest and in its most horrendous form For it is practically impossible for any one of them to order the cutting of 30 cords of stove wood from trees wrecked by an ice storm, or of 5 M F B M (as they say) of dimension lumber from mature forest stand, without entertaining immediately a stream of protests from outraged conservationists

Not only does this conservation ad absurdum place an inhibition upon the cutting of timber, but the same patriotic protest rises against other forms of use, grazing, for example. Now it happens that nearly all forests include grazing lands. The herding of cattle, sheep, hogs, deer and other cattle on the forests has been prac-

A Canadian Lake—One of Millions

ticed from time unremembered—long before Columbus discovered America or Roosevelt discovered conservation. To-day the National Forests, to mention only one example, are grazed annually by about 14,000,000 cattle, sheep and horses The meat, wool and leather produced are worth many millions of dollars Yet with no less regularity than Old Faithful's eruption of steam and boiling suds comes the eruption of steamy alarm that the forests are being ruined by the sheep. Of course sheep can spoil a forest, and especially can they prevent the timely reproduction of a new stand of trees At the same time it is wholly practicable to graze treeless



YOUNG WHITE PINE STAND IN A PRIVATELY OWNED MASSACHUSETTS FOREST

areas within forest boundaries (there are many such areas, some of them of considerable extent), and it is also perfectly possible to graze good woodlands at certain times and seasons without the slightest injury to growing timber

In English, French and German forests, long famous for good administration, the commercial production of wild game is an established practice. Considerable numbers of deer, especially, are raised and slaughtered for food just as simply as beef is raised in Missouri and dressed in Kansas City. It would be entirely feasible to adopt a similar practice in American forests, but one shudders to think of the personal abuse which would descend upon any officer who would sanction the killing of "those beautiful deer" (which, by the way, the most violent protestants have never seen) There is at least one forest in America now which is over-stocked with

Fine Rambouillet Sheep Grazing in the Dixie National Forest, Southern Utah

deer, where the numbers might be reduced to the benefit of the animals themselves, and where the older members are dying as naturally and as uselessly (anthropocentrically speaking) as the senile trees which shelter them. But what would be said by all those useful societies for the conservation of wild life if two thirds of the mature bucks in this herd were put on the market by the meat packers along with the beef and mutton which now pastures the same ranges? Such a step would be altogether rational, but it wouldn't get an encore from our conservation audiences.

Indeed there seems to be a sort of prejudice against all forms of practical use The forest, it would appear, is to be reserved for esthetic enjoyment. While this is precisely the particular forest use in which I am personally most interested, and which I firmly believe ranks above all other uses, yet it is foolish to prohibit other uses, especially when they do not in the slightest interfere with our pet "higher uses." Perhaps our conservationists in excelsis et extremis will some day discover that water is one of the leading commercial products of the forests, that enormous quantities of it are being used through the week to turn machinery and on Saturday nights for baths and all day long for drinking purposes. When they learn of this commercial degradation of the forests they should, to be consistent, prohibit the removal of water from "the lands of the state, now owned or hereafter acquired constituting the forest preserve," as it says in the Constitution, Art. VII, Sec. 7 *ibid.* This prohibition of drinking water would be more popular in certain select circles than other constitutional provisions now in force, and it would be just as good conservation as some which now stands in the schoolbooks and the library books and the statute books.

What we really want is "conservation with teeth in it"; also with backbone enough to stand upright, with legs enough to travel on and with brains enough to know where it is going

—*Recently photographed by Julian P Scott*

DR DAVID STARR JORDAN

Dr Jordan, chancellor emeritus of Stanford University, was elected president of the Pacific Division of the American Association for the Advancement of Science at the recent Los Angeles meeting Dr. Jordan was president of the American Association in 1909.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

OUR UNEASY EARTH

WHENEVER a shake-up like that in Japan occurs we take thought of our underpinning. Is this solid earth so solid as it seems? Is not the crust likely to cave in any time, and if so what sort of a furnace shall we fall into? Will the earth open her mouth and swallow us up and our houses and our goods and close in upon us as it did upon the men of Korah who ventured to oppose Moses?

Such fears we may well have felt in our youth when we were taught that the earth was a molten mass held in by a thin solid crust. As the hot kernel of the earth cooled it would naturally shrink away from the outer shell, leaving it unsupported like the ice bridge over a dwindling stream. No, that is a highly inappropriate simile, let me say rather like an ill-baked cake. Perhaps the basaltic dough out of which our world was molded might not have been mixed right and might collapse in the cooling with disastrous results to us animalculae who dwell upon its upper crust.

Also we used to be told that this shrinkage of the earth caused a crumbling of the crust into mountain ranges, and the professor of geology showed us just how it was done by rumpling up the table cloth or the pages of his manuscript by shoving his hands together from both sides. We therefore lived in dread lest a new Himalaya might arise at any moment in our midst and catch us on its peak or slippery slope.

But better knowledge of the composition and character of the materials that form our globe has given new ideas of its interior and new theories of its mountain formation and earthquakes. It is now held that the earth is as rigid as steel to sudden shocks and as plastic as putty to long continued pressure. Don't say that is an impossible combination of qualities, for you can easily prove that it is not. If you give a sharp tap to an ordinary phonograph record you will knock a piece out of it. On the other hand, if you lay it on an uneven surface and pile books on it you know that the disk gradually warps out of shape and gives awful music. So the earth, behaving like a rigid body, will crack under a local strain and transmit the vibrations of it swiftly to all parts of the world and yet the continents float upon its plastic mass so stably that their rise and fall is imperceptible. The pressure is so great at a depth of some sixty miles that the rock will flow and therefore each section of crust sinks to its proper level and remains in perpetual balance with all the rest of it.

This is known as the "isostasy" theory and has been chiefly worked out by Hayford and Bowie of the U. S. Coast and Geodetic Survey. According to them mountains are not formed by crumbling but by swelling. As the mountains are worn away through erosion by wind and water, the sediment carried down by the rivers is deposited on the edge of the sea. This transfer of material from the mountains to the sea above ground is compensated underground by the slipping of an equivalent amount of the hot viscous material to the base of the mountain so that the mass of the mountain area and of the ocean area remain the same. Mountains may therefore be pushed up from below as they are being rubbed off on top. But

not at the same rate, for the material forced into the crust from below a mountain area is denser than that eroded from the surface, hence the mountain area will be gradually worn down to a low elevation. So the material of the rocky crust of the earth contracts and expands, rises and falls, erodes and deposits. We find ocean fossils on top of the mountains and some parts of a continent may have submerged and emerged repeatedly in the course of time. Where the mountains are old and worn down and the land has been leveled, there is little likelihood of earthquakes, for the crust has practically reached equilibrium. But where the mountains are young and rise sharply from the sea there are still adjustments to be made and these cause slips and jerks comparatively slight in amount but sufficient to bring disaster upon the puny works of man.

A PSYCHOLOGIST UNDERTAKES TO EDUCATE CHIMPANZEES

ALREADY the revival of the controversy about man's origin by "special creation" or by "evolution" has given a new impetus to research. Dr. Robert M. Yerkes, psychologist and student of animal behavior, has undertaken an intensive study of the chimpanzee, one of the man-like apes. There are only three kinds of great ape, the gorilla, the chimpanzee and the orang-utan. Of these the chimpanzee is perhaps most like man in its behavior.

Dr. Yerkes's pair of young chimpanzees were brought to him from Africa. It is reported that he originally named them Adam and Eve and called their garden home Eden! But more recent account has it that "sense" vanquished "sentiment" and the animals are now known as "Chim" and "Panzee." Thus, doubtless, the scientist hopes to avoid wounding the sensibilities of Adams and Eves of the genus homo and increasing prejudice against the anthropoid apes in those who consider evolution anti-religious.

Chim is a little "blackface" chimpanzee from the Belgian Congo. He is thought to be about 14 months old and he weighs about 20 pounds. Dr. Yerkes says it would take a lively child of three to keep up with him at play or in solving problems which depend on manual skill and dexterity. Panzee—a name peculiarly appropriate to the female of the species—is a "whiteface" from British West Africa. She is somewhat larger than Chim, but weighs less, although she is thought to be about 18 months old.

The chimpanzee couple will winter in Washington, where Dr. Yerkes plans to seek answers to such questions as: Can the chimpanzee be taught to speak? Already he knows that it can understand much that is said to it. Has it ideas and can it solve practical problems in novel and original ways? Does it of its own initiative use objects as tools? The doctor says Chim acts more "intelligently" and "reflectively" than a child of his age. To what extent is the chimpanzee educable? Can it acquire scores or hundreds of habits, if trained systematically as is the child?

Dr Yerkes has had a great deal of experience in educating animals of all grades from earthworms to college students. He succeeded in training earthworms to find their way out of a maze so thoroughly that they would retain their training even after their heads were cut off. This experiment was not tried on college students. But I should be willing to wager that the chimpanzee will not learn as much from him as he will from them.

Man's superiority over all other creatures of earth, water and air seemingly is due to intelligence. Careful, skillful, long-continued study of the growth and development of the chimpanzee, and especially of its intelli-

Dr. Yerkes with "Chim" and "Panzee"

gence and its emotions may throw invaluable light on the nature and development of mind in general. This certainly would be worth while, for mind surely is the most fascinating aspect of Nature.

The task which Dr Yerkes has set himself is as difficult as it is important, for the great apes, to be reared successfully and kept in good health and spirits, must be treated much as children Little is known with certainty about the habits, life history and mental life of any of the apes. This is chiefly because of the discouraging difficulties in obtaining, keeping and studying them But why journey to darkest Africa—or for that matter lightest Africa to study the nest-building instinct (or is it tradition) of the chimpanzee when you can see a tree-nest built by one of these ridiculously and pathetically man-like animals in your own back yard!

Reports of Dr Yerkes's discoveries in the realm of ape mind will be eagerly and impatiently awaited by those who consider the chimpanzee to be man's cousin as well as by those who deny their relationship to him.

THE FAITH OF THE SCIENTIST

THE things we are surest about we do not talk about We do not have to There are certain things that all sensible men take for granted and there is no use in trying to convince those who are not sensible But once in a while it is well to dig down to the very foundations of our faith to see what they are

There is one principle that underlies all the sciences as it does all ordinary life and yet is not often specifically pointed out

This is the invariance of nature or the constancy of cause and effect That under the same circumstances the same thing will happen always anywhere This is a bit vague, for of course the circumstances are never twice the same all through the universe. And nobody can prove it or tell why it must be so

For instance, who knows if the law of gravitation will hold true tomorrow? Why should not all particles of matter repel one another instead of attracting one another?

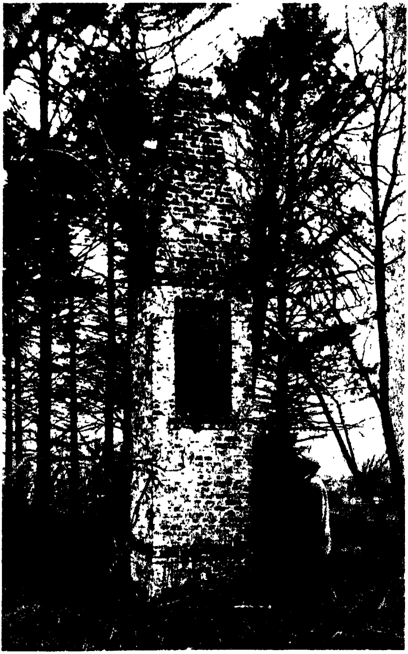
Suppose some erratic oak tree, in a desire to be original, should begin to bear watermelons instead of acorns? Who is entitled to tell it that it can not? Suppose the earth should get tired of always turning the same way and take a notion to turn from east to west for a change? How do you know it won't? You don't know Yet you are sure it won't.

The only reason you can give is that this never has happened, but that is merely the prejudice of the conservative, the negation of all progress.

Yet this principle, that like causes always produce like effects, has to be assumed by pure faith before we can undertake our next day's work. It is also a necessary assumption in all scientific calculations. Let us consider, for instance, the astronomer, for he indulges in longer term prophecies with greater assurance and success than any other scientist. The point is best put by a French poet, Sully-Prudhomme, in a beautiful sonnet that may be translated as follows:

The Rendezvous
By Sully-Prudhomme

'Tis late, the astronomer his vigil stern
On lofty tower prolongs. In silent space
He seeks his golden isles, nor turns his face
Till the starry host grows pale with morn's return.
Bright worlds, as grain the winnowing flail doth spurn,



MEMORIAL TO A METEORITE

Situated near Wold Newton Hall, East Yorkshire, England The slab bears the following inscription On this spot, Dec 13th, 1795, fell from the atmosphere an extraordinary stone. In breadth—28 inches, in length—30 inches, and whole weight—56 lbs This column, in memory of it, was erected by Edward Topham 1799

Fly past thick-clustering nebulae a-light;
His eager gaze one streaming orb pursues in flight,
He calls: "This hour, ten centuries hence, return."
Return it shall. Nor time nor space abates,
The Everlasting Fact it never can assail.
Men pass from view; Eternal Science waits.
An though Humanity itself should fail,
Fair Truth will stand, alone, upon the tower
To keep that tryst at the appointed hour.
(Translated by F. P H.)

Now I fancy that Sully-Prudhomme with poetic license has exaggerated a bit the marvelous power of prescience possessed by the astronomer. To fix the exact hour for a comet's return a thousand years in advance is rather closer figuring than we can do with certainty. There is always the possibility that the comet may be wrecked in a collision or sidetracked by some star.

But Sully-Prudhomme does not exaggerate the confidence of the scientist in his fundamental principle of the constancy of natural law. The astronomer is willing to stake his life, or what he values more, his scientific reputation, that if none of these accidents happen and if he has rightly weighed all the factors involved, the result will be exactly as he says He is so sure of it that if a comet does not return on an expected date he will be confident that some unforeseen force has intervened and he will set about to find it. If he does not find out what is wrong, other astronomers will take up the task and devote their lives to finding the cause of the discrepancy They may keep at the problem for a thousand years and never think of saying: "Well, perhaps there isn't any reason Comets are queer things any way."

And if an oak tree should take to bearing watermelons—things almost as unexpected have happened—the botanists would be absolutely positive there was something new inside or outside the tree that set it to acting so. They would start to experimenting and probably find out what it was in the course of time "There's a reason" is the faith of the scientist and so far he has never been belied.

THE SCIENTIFIC MONTHLY

DECEMBER, 1923

THE COMMON SENSE OF THE THEORY OF RELATIVITY[1]

By Dr. PAUL R. HEYL

U. S. BUREAU OF STANDARDS

THE word gravitation can not be mentioned nowadays without bringing to mind the two names Newton and Einstein. Newton's connection with the subject is familiar to all; but what has Einstein done that his name should be mentioned in the same breath?

Let us recall briefly Newton's claim to remembrance in this connection. The explanation of the falling of bodies as due to an attractive force exerted by the earth was, of course, not original with Newton. The conception was familiar to Galileo; it was known to Aristotle. Even the law of the inverse square had suggested itself to more than one mind before the publication of the Principia. Newton's especial contribution to the subject was the conception and demonstration of the universality of gravitation according to the inverse square law as a sufficient explanation of the motion first, of the moon around the earth, then of the various planets around the sun, and, finally, by a legitimate extrapolation of the motions of every member of the stellar universe.

Every hypothesis as to the cause of things, no matter how flawless in logic and sound in mathematics, must stand the test of experiment before final acceptance. In the case of the Newtonian law of gravitation this test occupied many years and involved long-continued observations of the planets. For decade after decade the motions of these bodies were observed to follow with exquisite accuracy the paths prescribed for them by the law of inverse squares. With the passage of time not only did instruments become more perfect, but with the interval of years for comparison measurements became increasingly accurate; yet so closely had Newton cut

[1] Published by permission of the director of the Bureau of Standards of the U. S. Department of Commerce.

to the line that over a century elapsed before any serious divergence of observation from theory became noticeable. Finally, Leverrier, in 1845, called attention to the fact that the planet Mercury showed a slight irregularity in its motion, inconsistent with the law of inverse squares, and too large to be explained as an error of observation. This discrepancy has been confirmed by later astronomers. The seriousness with which it has been generally regarded is shown by the fact that all other attempts to explain this anomaly having failed, the radical proposal was made to alter slightly the Newtonian law by changing the exponent 2 to 2.000 000 1612. This was first suggested by Asaph Hall, the discoverer of the satellites of Mars, and was for some time favorably regarded by no less an authority than Newcomb, who abandoned it only after E. W. Brown showed that the motion of the moon did not allow of even this slight departure from the whole number 2. The anomalous behavior of Mercury thus remained an unexplained puzzle. The simplicity of the Newtonian law of inverse squares and its inherent reasonableness and probability on geometric considerations weighed heavily in its favor; so much so that repeated failures to account for the irregularity of Mercury by the presence of unrecognized attracting matter gave rise to a tendency in certain quarters to throw doubt on the reality of the alleged discrepancy.

Such was the state of affairs when Einstein appeared upon the scene with his now famous law of gravitation. This law had little in the way of intrinsic attractiveness to recommend it. As opposed to the simplicity which characterizes the law of Newton that of Einstein is complex in the extreme. Where Newton's law takes the form of a single differential equation, that of Einstein is expressed by a set of ten simultaneous differential equations, each of so fearful and wonderful a structure that a most compact and unfamiliar notation is required to render it fit to print. Theories far less formidable have fallen of their own weight, but that of Einstein has gradually compelled recognition, despite its repelling appearance, solely upon performance, by reason of its ability to furnish results; for it not only explained everything which the Newtonian law explained, and equally well, but it also, without forcing, explained the great puzzle of the irregularity of Mercury. Nay, more: it undertook the always precarious business of prediction, for it indicated the existence of a phenomenon hitherto unobserved, the deflection of a ray of light under the intense gravitational forces existing near the sun. This prediction has recently received the final stamp of experimental verification in the results of the 1922 eclipse expedition of the Lick Observatory. Additional weight attaches to these results from the fact that Director Campbell was known to have had no bias in Einstein's favor.

Such a record of performance on the part of a new theory demands for it the serious attention of all who profess and call themselves physicists. To obtain a proper perspective for the understanding of the subject it will be well for us to review briefly the history of the theory of gravitation.

Among the various different phenomena studied by the physicist gravitation, since the time of Newton, has stood in a class by itself. For the rest, the unification of physical phenomena has gone on apace. Heat lost its individual status as an imponderable entity (caloric), and took its place as one of the many forms of that protean concept, energy. Relations were found between magnetism and electricity, and between electricity and light. Even matter itself is now recognized as electrical in its structure. Gravitation, however, held itself aloof, steadily refusing to show any kinship to other physical phenomena. True, there is a superficial resemblance to the attraction of magnetic and of electrified bodies; but with the law of inverse squares the resemblance ends; for magnetic attraction can be cut off by a suitable screen and is greatly influenced by change of temperature; and in electrostatics we have the phenomenon of the dielectric constant, the effect of the intervening medium. Nothing of this kind obtains in gravitation. Much experimental work has been done in the hope of discovering something with which gravitation varies, but all results have been negative. Experiments with the pendulum, in the hands of Newton, and later of Bessel, have shown that gravitation is independent of the nature of the material. The precision reached in Bessel's experiments was about one part in 60,000. It is interesting to notice that among the substances tested by him were meteoric iron and meteoric stone. More recent experiments by Eötvös, with the torsion pendulum, have carried the precision to one part in two hundred million. Recent experiments at the Bureau of Standards have shown, to a precision of one part in a billion (10^9) that gravitation does not vary with the orientation of a crystal in the gravitative field of the earth. It is also known that gravitation is not a function of the temperature, and, in spite of certain recent claims to the contrary, it appears well established that the mass of the whole earth exerts no perceptible gravitational screening effect. In fact, gravitation seems to be a function of nothing but the mass involved and the space coordinates of the system.

Nor has speculation been idle. Newton, officially, in his formal publications, "framed no hypotheses"; but his letters show that privately he speculated freely, as every scientific man should. Many speculative theories as to the cause of gravitation have been propounded. The Smithsonian Annual Report for 1876 contains a collection of all the hypotheses of this nature which had found

their way into print since the time of Newton, some twenty-five or thirty in number. Since that time perhaps half a dozen more might be added, such as that proposed by Osborne Reynolds. Needless to say, none of these hypotheses is to-day of more than historical interest.

As a net result of all this theorizing and experimenting we may say that at the beginning of the twentieth century our knowledge of gravitation was just where Newton left it. Negative results there were in plenty, but nothing positive. Then came the Einstein theory, giving us the two important results before mentioned, the first positive advances in the theory of gravitation for two centuries.

The Einstein theory of gravitation may be compared to the castles of medieval Europe. Their stone walls were proof against the means of attack known in those days, yet these strongholds had always a vulnerable spot, the gateway by which they communicated with the outside world. By this gateway they were usually attacked and often taken.

And so it is with the theory in question. It is self-contained, logically consistent, and, I believe, mathematically impregnable; yet it connects with the physical world by a fundamental postulate which must, in the last analysis, be justified by experiment. If this postulate fails, the whole theory falls with it. This postulate is called the Principle of Equivalence.

I have said that gravitation is in a class by itself among physical phenomena. This is not quite true; for Einstein was the first to point out that there is another phenomenon of very much the same order, namely, inertia, especially in the form known as centrifugal force. Centrifugal force is independent of the material, is not a function of the temperature and can not be cut off by any form of screen. In fact, centrifugal force, like gravitation, seems to be a function only of the mass involved and the space (and time) coordinates of the system.

Guided by this parallelism of phenomena Einstein formulated his principle of equivalence of gravitation and inertia, their identity of nature and the consequent impossibility of distinguishing between them. In the whole history of gravitative speculation there is no parallel for this; the idea is entirely original. All previous theories had attempted in some way to account for the existence of a force drawing together the attracting bodies, usually by supposing them pressed together from without by an intercepted flux of some more or less vague description. Einstein takes absolutely new ground. Instead of trying to supply machinery for the production of a force of attraction he denies the existence of such a force. According to his theory there is no more force of attraction between the sun and the earth to hold the latter in its orbit

than there is centrifugal force of repulsion preventing it from falling into the sun. Both so-called "forces" are mathematical fictions; both are but different aspects of the one entity, inertia.

Einstein did not make this novel assumption without a certain experimental foundation. The equality, or at least the proportionality of the inert mass and the gravitational mass of a body is, as we have seen, one of the most precisely determined facts in nature; and the failure to detect any gravitational difference in crystals which are in every other respect (save inertia) anisotropic definitely puts gravitation and inertia into one class and all other crystalline properties into another. Under the Newtonian law this close proportionality or equality of inert and gravitational masses appeared only as a curious but accidental coincidence. In the Einstein theory it is the foundation stone.

The principle of equivalence is sometimes stated in formal and mathematical language as follows: "Every natural gravitative field of force is equivalent to an artificial field of inertial force resulting from a suitable change of coordinates."[2]

This is a hard saying; but such is its importance that it is worth our while attempting to arrive at a clear conception of its meaning.

According to an interview published several years ago in the daily papers, Einstein's mind was turned in this direction by witnessing an accident. The story is curiously suggestive of that of Newton and the falling apple. It appears that Einstein saw a man fall from a scaffolding, land on a pile of brush and escape without serious injury. Einstein, who appears to be of a naïve frame of mind, interviewed the victim of the accident and asked him whether, while he was falling freely through the air, he felt the pull of the earth drawing him down. A trained observer might well doubt whether his state of mind under the circumstances would be suitable for the making of scientific observations; but the person in question took Einstein seriously and assured him that he had no recollection of anything of the kind. This answer was apparently what Einstein expected. "Yes," said he, "this man's coordinates were changed from a stationary to a moving system with just the proper degree of acceleration to neutralize the gravitative pull of the earth."

Another illustration that may help us in this connection is that of an elevator. Imagine an elevator with closed walls, containing an observer. The elevator will be supposed first at rest. If a bullet be fired through the elevator walls from without, the path of the bullet will appear to the observer within as a straight line from wall to wall, though not necessarily horizontal. The same will be true if the elevator be in uniform motion. But if the elevator be

[2] Eddington: Freundlich.

in accelerated motion, say upwards, the path of the bullet will no longer appear straight, but as a curved trajectory, convex upwards. The observer might account for this curved path by saying that the bullet moved according to the resultant of two forces: its original impulse, causing by itself a straight path from wall to wall, compounded with a force of attraction of some unknown nature drawing the bullet downward toward the floor of the elevator.

Another illustration used by Einstein is that of a revolving disc. Suppose a large horizontal disc capable of carrying an observer, such as may be seen in amusement parks. Let the disc be covered by a large dome-shaped lid, so that the observer within can not tell by direct observation whether or not the disc is in rotation. Suppose the disc is at first stationary. The observer, in walking from one point to another of his little world, would perceive no difference at any point from any other. But let the disc be in rotation, and, though the observer could not directly perceive the motion, he would become aware of a difference. At every point of his space except the exact center he would experience a force repelling him radially outward; and the greater the distance from the center the greater the force of repulsion. He would, in fact, be living in a sort of turned-inside-out gravitational field. This "force" of repulsion is, however, purely inertial in its nature. Moreover, this force, being proportional to the square of the speed of rotation, will be the same whether the disc rotates in a negative or in a positive sense; but if we suppose the disc given an imaginary velocity of rotation, $v\sqrt{-1}$, the force experienced by the observer will now be proportional to $(v\sqrt{-1})^2$ or $-v^2$; in other words, the force will now be an attraction toward the center, still more closely simulating gravitation, though still strictly inertial in its origin.

Imperfect as are these illustrations as attempts to represent the actual gravitational field of a body, they nevertheless help us to understand what Einstein means by saying that a gravitative field is equivalent to an inertial field produced by a suitable change of coordinates; yet none of these suggestions furnishes us with a change of coordinates completely adequate to the representation of the actual three dimensional gravitative field of a particle. The task of finding such a coordinate system, if indeed any should exist, might well appal the best equipped of mathematicians; yet with sublime confidence in his intuition, it was to this task that Einstein set himself.

And then a wonderful thing happened; for, with but the slenderest of clues and guided principally by what we may fairly call the intuition of genius, he succeeded! He found a transformation of space and time coordinates which represents even more accu-

rately than Newton's law the actual physical phenomena of the gravitative field of a body; which fits closely the singularities in the motion of the planet Mercury and in the path of a ray of light very close to the sun; a transformation which fully justifies the bold assertion of the principle of equivalence that a natural gravitative field may be perfectly replaced by an artificial inertial field created by a change of coordinates.

And what is the nature of this new coordinate system? Is it that of a falling man, a rising elevator or a whirling disc? No, it is none of these, nor does it remotely resemble any one of them. It is a concept transcendental in the extreme, for it supposes space to be four-dimensional and non-Euclidean in character, curved or warped slightly in a fifth dimension!

Here we have another hard saying. Let us step down two dimensions to render our words mentally picturable, and consider a space of two dimensions curved in a third dimension.

Imagine a level surface of still water of indefinite extent; this surface will be two-dimensional, having length and breadth, but no thickness. The surface being perfectly flat, the geometry of figures traced upon it will be Euclidean, that is to say, the sum of the angles of a triangle will be exactly 180°, and through a given point only one parallel can be drawn to a given straight line. But suppose the surface, instead of being flat, is spherical, like the surface of the ocean viewed on the large scale; the geometry of figures traced on such a surface will then differ importantly from that of figures on a flat surface. On a spherical surface we can not, of course, draw a straight line in the usual meaning of that term; but we can draw one after Euclid's definition: the shortest distance between two points; and, as every navigator knows, this will be an arc of a great circle. There is a name used in general for such a shortest line traced on a curved surface of any kind: it is called a geodesic line. Its actual shape will, of course, depend on the way the surface is curved and the direction in which the line is drawn. On a cylinder, for instance, a geodesic may be a straight line, an arc of a circle or some intermediate form, according as it is drawn parallel, perpendicular or oblique to the axis of the cylinder.

On our spherical surface the three angles of a triangle (constructed of geodesics) will exceed 180° by an amount proportional to the area of the triangle. This is called the spherical excess. And upon such a surface two arcs of great circles will always intersect each other if sufficiently produced; that is to say, through a given point no geodesic (or "straight") line can be drawn parallel to (that is, not meeting) a given geodesic. A surface possessing these geometrical properties is called a surface of positive curvature.

On such a water-surface a floating particle, if set in motion, and free from the action of all forces, frictional, attractional or otherwise, would travel by the shortest, "straightest" path it could find, obeying Newton's first law of motion with the added condition of being confined to the spherical surface; that is to say, on a curved surface, the natural path of a body moving under the action of no force is a geodesic.

Surfaces of negative curvature may be constructed, on which the geometry is just the opposite of that on a surface of positive curvature; for on such a negatively curved surface the three angles of a triangle sum up to less than 180°, and through a given point more than one geodesic can be drawn parallel to (*i.e.*, never meeting) a given geodesic. Examples of such surfaces are the stem of a wine glass, a saddle, or a mountain pass. On such a surface the geodesic, from a Euclidean point of view, would be a curiously twisted line.

To sum up, we may say that a space is Euclidean if the geometry of figures drawn in it obeys the traditional postulates of the Euclidean geometry, and in particular that one which assumes that through a given point only one parallel can be drawn to a given straight line. If the figures drawn in a space do not conform to this postulate the space is said to be non-Euclidean.

Returning now to our flat surface of water, let us render it non-Euclidean by curving it in still another fashion. By careful manipulation it is possible to lay upon the surface of the water a particle of a heavy body such as lead, or even gold, so that it will float. The only thing necessary is to avoid breaking through the surface. The particle then lies supported by the unbroken water surface bent into a cusp or depression. Here we have a surface, normally two dimensional, bent or depressed slightly in the direction of a third dimension in the vicinity of a particle of matter. If we examine the geometry of figures traced upon the curved portion of the water surface, we shall find it non-Euclidean, and of negative curvature. The geodesic of this part of the surface will be a curved line of some kind; but if continued well beyond the cusp in either direction the geodesic will soon be indistinguishable from an ordinary straight line, and the geometry of these distant portions of the surface will be Euclidean.

Suppose now a comparatively heavy particle thus floating and forming a rather deep and widely extended cusp. At a great distance, in a Euclidean region of the surface, suppose a much smaller and lighter particle, which hardly produces any cusp, moving freely along the surface in a direction that will carry it past the heavy particle at a short distance, well within the latter's cusp. The path of the moving particle, at first a straight line, will as it enters the

cusp gradually assume the curved or geodesic form proper to the space in which it finds itself. Assuming no attractive force to exist between the particles, the moving particle will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected in passing through the cusp the final straight portion of the path will not in general be a continuation of the first straight portion. The particle will have suffered a permanent deflection.

An observer watching the motion of the particle through what we may call Euclidean-Newtonian spectacles, which do not show him the curvature of the water surface, will say: "Yes, on passing the heavy particle the light particle seems to have suffered a force of attraction of some kind, and to have been deflected from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say: "No, I see now that there was no force of attraction at all. It was purely the inertia of the moving particle combined with the peculiar curvature of the surface which it had to traverse that produced the change in its path."

So much for a two-dimensional surface curved in a third dimension. Einstein's equations describe an analogous phenomenon occurring in a space of four dimensions curved or cusped slightly around each particle of matter, in the direction of a fifth dimension. A ray of light coming from a star traverses for millions of miles a region of space remote from material bodies, and consequently "flat" or Euclidean. Through this region the path of the light ray is a straight line. But if it eventually passes close by the sun, whose great mass causes a considerable cusp or warp in space, rendering it non-Euclidean in the immediate vicinity, the straight line becomes twisted into the geodesic proper to a space of such a curvature; and when it again becomes straight it has been permanently deflected from its original course.

The concept of a fourth dimension has been laughed out of physics many times since Lobatchevsky's day, but it has always returned, and would seem now to be more firmly entrenched than ever.

"But what is all this?" says some one. "In your title, which inveigled me into reading thus far, you promised to confine yourself to common sense; and now what are you doing?"

The Einstein theory has been called many bad names; "repugnant to common sense" is one of the mildest of them. But we may submit in this connection that there is another theorem respecting gravitation, or at least center of gravity, which, though accepted as orthodox and unobjectionable, is, if taken literally, as unreal, as absurd, as repugnant to common sense as anything in Einstein.

In calculating static moments we are accustomed to assume that the entire mass of a body is concentrated in its center of gravity.

"Oh, but," you say, "this is only a mathematical fiction, a short cut. Bodies behave *as if* this was so. Every one understands it."

Well, why not be charitable enough to extend the same tolerance to Einstein? Why not say that bodies behave *as if* space were curved, and *as if* gravitation were nothing but inertia? Does not this supposition fit the facts more closely than anything that has ever been proposed before? Regard it, if you will, purely as a mathematical fiction, with no physical reality necessarily behind it. What is real? "What is truth?" Pontius Pilate was a philosopher.

This, I believe, is the common sense of the theory of relativity.

Not only *may* we regard the theory in this light, but, I think, we *must*. We have considered the theory so far in its most favorable aspect; we have allowed it to put its best foot forward. Yet there is more of the story to tell.

Fitting a theory to the facts of Nature is much like fitting an equation empirically to a natural curve. It is not difficult to do this for a short piece of the curve; sometimes several equations are equally satisfactory; but if we need an equation that will hold over a more extended range it is not always easy to obtain a close fit at all points. So it is with the curve of Nature. We desire to find an equation which will fit it over at least as much of its range as is concerned with gravitation. The Newtonian equation does this almost perfectly; but there is one little kink in the curve, caused by the planet Mercury, into which the Newtonian equation is too smooth to fit; and when we follow out the curve into regions until recently unknown we find the Newtonian equation begins to diverge widely. Throughout this whole range the Einstein equation follows perfectly the curve of Nature, fitting the little Mercury kink, and running closely in the newly discovered region of the relation between light and gravitation, where the Newtonian equation parts company completely.

But Nature's curve runs on indefinitely; how far will the Einstein equation follow it?

Perhaps it may not go much farther.

I have said that the Einstein theory undertook the always precarious task of prediction; and in one case (the gravitative deflection of light) it succeeded spectacularly. But the theory contains yet another prediction. It indicates that certain lines in the solar spectrum should be shifted slightly out of place. The amount of shift indicated is very small, and difficult to pick up with certainty in the presence of pressure-shifts, Döppler effect and other corrections. While no final verdict has been reached, there does appear

to be some evidence unfavorable to the theory;[3] and certain of Einstein's enthusiastic followers have raised the question as to whether this point is really a necessary consequence of the theory. Einstein himself maintains, however, that this point is as vital as any other, and that if the experimental verdict is finally against it the whole theory is discredited.

I think we may see in this utterance of Einstein how sanely he regards this child of his brain. Being a mathematician he naturally recognizes the empirical equation fitted to a curve as something totally different from the real equation, and bound to diverge from it if carried out far enough. "No amount of experimentation," Einstein is reported to have said, "can ever prove me right. A single experiment may at any time prove me wrong."

But where the theory of relativity shows most plainly its artificiality is not in that part of it dealing with gravitation, but in the older or special theory, as it is now called, published some ten years before the gravitational or general theory was announced, but rounded out and completed only after the latter publication. This part of the Einstein doctrine was inspired by the negative result of the Michaelson-Morley experiment and similar attempts to detect our absolute motion through the ether, and is founded upon the postulate that it is impossible by any experiment that may be devised to detect our absolute motion in space. Physically, this appears to be true for motion of translation; but rotational motion is a different matter. Were the earth enveloped in perpetual cloud we could still, by the Foucault pendulum experiment, or by the gyroscope, detect its rotation. For this argument the theory of relativity has an answer of a kind; but, as Eddington says, when we come to rotational motion the theory of relativity stops explaining phenomena and begins explaining them away.

The answer of the relativist in this case harks back to the Ptolemaic astronomy. Where we are accustomed to consider a rotating earth, accompanied by a field of centrifugal force, surrounded by a relatively stationary universe of stars, the relativist considers a stationary earth and a rotating celestial sphere! Quite a step backwards to the dark ages? Well, it might be if his equations did not show that a hollow rotating body will apparently exercise a very small force on a body within it. A pendulum vibrating within a massive, hollow, rotating cylinder will, according to the Einstein equations, be deflected in the sense of the rotation, dragged around slightly by the moving mass. And the equations even indicate something simulating centrifugal force in a stationary system inside a hollow rotating mass.

[3] Additional evidence favorable to the theory has recently been adduced by St. John, whose earlier experiments were unfavorable.

Mathematically, the theory thus has an answer; but this answer, though mathematically perfect, lacks one very important property which Eddington calls "convergence."

To produce this quasi-centrifugal effect, which is very small, an enormous rotating mass is required; and the greater the radius of the rotating hollow body, the greater the mass needed. If the observed centrifugal effect upon the earth's surface is due to the rotation of the celestial sphere and the sum total of the mass of the fixed stars therein contained, this mass must be enormous, far exceeding any reasonable estimate that can be entertained. Either the dark suns of the universe must enormously outnumber those that are visible, or we must ascribe the effect to still more distant, and consequently much greater masses. The farther off we place the reckoning, the more we have to pay. The universe, on this hypothesis, is like a pyramid standing on its apex. Here, I think, the theory of relativity shows plainly its nature: a hollow mathematical shell, with no real content; useful when it fits the facts, useless where it does not. In this connection I may quote a pithy characterization once made to me about a person by a mutual friend: "Do I know Mr. X? Oh, yes; he's all right as long as he's all right."

The extreme to which this relativist line of argument might carry us is shown by considering several bodies like the earth, A, B, C. . . . If these bodies are not more than a light-year or so apart, they may all be considered as practically at the center of the celestial sphere if any one of them is. Suppose body A exhibits centrifugal force and bodies B, C . . . do not; how are we to account for this? Simply and easily, if we suppose A to be revolving and all the others stationary; but not so simply if we suppose A stationary, and the celestial sphere in motion; for to avoid a consequent production of centrifugal forces on B, C . . . the relativist must assume them in rotation also. Startling as this explanation is, it is no new thing under the sun; for the first of all relativists accounted for the apparent motion of surrounding bodies by the simple and soul-satisfying explanation: "Everybody's drunk but me."

In this brief review of the theory of relativity we have endeavored to keep a common sense perspective; to recognize its strength and to point out its weakness. Before closing we must discuss several points which do not fall exactly in either category: we must defend the theory of relativity from certain attacks which are unjustified.

One point about which a great deal of controversy has centered is the statement that the theory of relativity shows that a material particle can not have a speed exceeding that of light. This state-

ment is not found in Einstein's original papers. It is referred to as an error by Cunningham and by Silberstein; it is not mentioned, except in a modified and unobjectionable form, by Eddington. In Einstein's latest official utterances (his Princeton lectures) this statement does not appear; but it is found in a footnote, possibly from another's hand. It occurs also in several other American writings.

That the inertia of a moving charged body approaches infinity as the speed approaches the speed of light was known before Einstein, as a consequence of the classical theory, and found experimental support in the evidence furnished by rapidly moving electrons. No antagonism was aroused by this doctrine, as the source of this increased inertia was evident in the work spent in the production of a moving electro-magnetic field.

An important theorem in the older or special theory of relativity is concerned with two systems, A and B, B being in motion relative to A, and both systems being in communication by light signals sent from A to B. Certain formulas result which break down, or furnish imaginary values, when the speed of B (relative to A) exceeds the speed of light. It seems likely that some one, having in mind the pre-Einstein doctrine of limiting speed mentioned above, and regarding Einstein's formulas with more enthusiasm than discrimination, concluded somewhat hastily that there was some connection between them. As a matter of fact, it is, or should be, at once evident that the breakdown of Einstein's formulas is due to nothing more transcendental than the fact that if B is moving with a speed greater than that of light, A's light signals can never overtake B at all.

The theory of relativity has been criticized for doing away with the ether without offering any substitute explanation for the mechanism of propagation of light, and, in particular, for maintaining a dense silence on the subject of interference. To this, I think, the relativist may fairly answer that the theory contemplates the propagation of light only in its larger aspect, in its motion along the "path of least action," a geodesic in curved space, and with the phenomena deducible from this hypothesis. As for doing away with the ether, this process had progressed so far before Einstein that it was not uncommon to define the ether simply as "the nominative of the verb to undulate." As a matter of fact, Einstein's space is not at all bad as a modern concept of the ether; for it might be equally well described as "the nominative case of the verb to be bent"; and if it can be bent, why may it not vibrate? Why may we not have ripples superposed on the larger, static curvatures of material origin, and traveling according to the usual laws of the propagation of disturbances in an elastic medium? On this view,

there is little to choose between the old and the new. Matter is a static strain, a permanent deformation in space, ether, or what you will; and it is only necessary to endow Einstein's conception of space with elasticity as well as deformability to have at hand a fine structure capable of accounting for the optical phenomena about which the theory of relativity is silent.

Another matter can not be passed here without mention, as it has led some to the unjust generalization that there is something about relativity which has a tendency to turn a previously sane head. For this, also, one of Einstein's disciples is responsible. It is a remarkable thing that one who is easily the most brilliant expounder of Einstein, and who has served the present writer as a Rosetta stone to the Einstein hieroglyphics, should be obsessed by the delusion that when a quantity becomes unity it loses its dimensions. The mathematical consequences of such a procedure can lead only, as Lodge justly remarks, to confusion.

Perhaps this review may lead some one to read, or attempt to read, Einstein. It must be said that he is almost unreadable, even to a physicist with something more than the average mathematical equipment of his order. As a commentary to be recommended in all respects, mathematical or non-mathematical, we may suggest Freundlich's little book entitled: "The Foundations of Einstein's Theory of Gravitation," translated by Brose. For the older, or special theory, Cunningham is a sane and simple writer. Eddington is brilliant and mentally stimulating in his non-mathematical moments; but his mathematical writings are not to be recommended to the beginner.

As a general theory of the Cosmos, the Einstein theory is suggestive of the Ptolemaic astronomy. The Ptolemaic theory was not to be despised in its day. It was no mean conception and explained perfectly every astronomical fact known at that time. But even if there had been no Copernicus, the Ptolemaic theory would have broken down with the advent of Foucault. And so it is with the Einstein theory. For sheer complexity it out-Ptolemizes Ptolemy; and many of us, doubtless, recall with sympathy that profane but practical King Alphonso, who, apropos of the Ptolemaic system, regretted that he had not been present at the Creation; he could have suggested a better plan. Not that any one at present has a better theory to suggest than that of Einstein; but such a thing may and doubtless will come to pass when the hour and the man arrive. Newton cut so closely that over two centuries elapsed before an Einstein could better his formula; and how long it will be before the next corrective term is added to the empirical equation for the great curve of Nature is a matter at present on the knees of the gods.

RECENT DEVELOPMENTS IN IMMIGRATION

By Professor ROBERT DE C. WARD
HARVARD UNIVERSITY

THE LABOR SHORTAGE

AMERICAN industry has been suffering from a widespread shortage of labor. Of that there is no doubt. The situation has, however, been exaggerated and the causes which led to it have been misunderstood. It is a highly complex problem, and many factors are concerned in it. This labor shortage has been very generally but wrongly attributed chiefly to the three per cent. quota immigration law. People forget that labor shortages occurred before the days of restricted immigration, and that only during times of business depression has there been an abundant labor supply. When they agitate for a larger immigration from southern and eastern Europe they forget that the sweat-shop workers and peddlers who nowadays make up a considerable part of that immigration are not the sort of workers whom we need; and that ignorant pick-and-shovel men are not fitted to operate the agricultural machinery on a modern American farm. The effects of the labor shortage are also greatly exaggerated. The cry for more harvest hands in the wheat fields of the West is perennial, yet the dire predictions that the wheat crop will be ruined because of the shortage of men to harvest it have never come true. Again, in spite of all that Judge Gary and others have said about the difficulty of introducing the eight-hour day in the steel industry because of the inadequate labor supply, that most desirable change is nevertheless being accomplished. The "interests" which are calling for more labor really want cheaper labor. They are trying to prevent further restrictive legislation by carrying on a campaign against the present law.

It is a mistaken idea that the three per cent. law has reduced immigration to negligible proportions. The regular legal quotas permit an annual inflow of over 350,000. In addition, aliens who have lived five years in British North America, Mexico, Central America, the West Indies and South America, as well as a very considerable number of "excepted" classes, can come in without limit as to numbers. Under this provision, many thousands of immigrants have come from Canada and from Mexico. In the fiscal year ending June 30, 1923, over 500,000 aliens were admitted according to the official count, but tens of thousands of others were smuggled in or, having entered American ports as seamen, left their ships and became illegal residents here.

"A crude labor shortage is here to stay," as an editorial writer in one of our most influential industrial papers recently said, adding, "it would be most alarming if the prospects were otherwise." Our people as a whole are clearly determined that a flood of "cheap" alien labor shall never again enter our ports. They believe that the prosperity of the United States does not depend upon any such importation. They are convinced that this country is better off when every one is steadily employed at good wages than when hundreds of thousands of unskilled and ignorant foreigners are being landed every year, unsettling the labor market and greatly aggravating the conditions of unemployment in periods of business depression. Much of our labor is not effectively employed. In most industries the labor turnover is far too large. There are too many peaks and depressions of employment. Hundreds and thousands of men and women are at work only part of the time. Further, we have not begun to use labor-saving machinery as fully as we should. When men become too expensive, or when there are too few of them, labor-saving machinery takes their place. Countless jobs are to-day done by machinery which a few months ago were being done by ignorant foreigners. This is true of the farm as well as of the factory and the mine. It is infinitely better for the country that it should be so. Our future labor supply can be mainly recruited out of the loins of the people who are already here, and augmented by a limited inflow of selected alien immigrants. In the minds of competent authorities, there is no doubt that immigration, by reducing the native American birth rate, has not increased the population of the United States but has changed its character. Our population would probably be fully as large as it now is had there been no immigration at all since the foundation of the Republic. For the United States it is a clean-cut decision between developing our own labor supply here or perpetuating in our midst a definite coolie class, steadily recruited through the immigration of unskilled alien laborers. The patriotic course for our large employers to pursue is to stop complaining about the "need of labor"; to set themselves to work to reduce their labor turnover; to introduce labor-saving machinery; to improve working conditions; to face the facts of the situation. An intelligent American, with an American-made machine, can do the work of a dozen ignorant foreigners. This is good sense. It is good business. It is a sound American policy. And it will greatly decrease the distress of unemployment when business conditions are bad. Mr. Edward A. Filene, of Boston, a large manufacturer and employer, has put the economic situation clearly as follows: "Employers do not need an increased labor supply, since increased use of labor-saving machinery and elimination of waste in production and distribution

will for many years reduce costs more rapidly than wages increase and so prevent undue domination by labor."[1]

The Monthly "Race" to Quarantine

With the beginning of the new fiscal year (June 30, 1923) and the opening of the new quotas, there again occurred "races" to quarantine of immigrant-carrying steamships. "Sob-stuff" stories of the hardships of aliens who had to be debarred because they exceeded the regular monthly quotas were prominently displayed on the front pages of the daily papers. What are the real facts in this situation?

Under the law, 20 per cent. of the total annual quota of any nationality may be admitted in any one month. Because of this provision, we have a tremendous rush in the first few days of the first five months of the fiscal year, with the resulting congestion, hardships, and, unfortunately, very hurried and inadequate medical and general inspection. The difficulty here is far less a defect in our law than a failure on the part of the steamship companies to take proper precautions to obey the law. Under the law, express provision is made for the issue, by the Immigration Service, of frequent and regular statements, showing just how many aliens of each nationality are still admissible. Every facility is given to the steamship companies to ascertain the exact status of the quotas at any time. But the majority of these companies—there have fortunately always been a few exceptions—have acted on the assumption that they have vested rights in the United States as a dumping ground for their human cargoes. They prefer to take the chance. They are primarily interested in getting the steerage passage money The result is that many perfectly honest aliens are brought over, expecting to land, and then have to be deported. The trouble is not with the law. It is with the steamship companies, which, it may be added, have a good many reasons for wishing to make every restrictive immigration law appear inhumane, unjust and non-workable. The Commissioner of Immigration at New York clearly laid the blame where it belongs when he said of the steamship companies that they are "dealing in dividends of human beings to satisfy their own greed." This is the whole situation in a nutshell.

The Geddes Report on Ellis Island

A very unnecessary flurry was caused by Ambassador Geddes's report on conditions at Ellis Island. A careful reading of that report fails to show that there are any very serious evils at our principal immigration station which, under the conditions of congestion

[1] *Sat. Eve. Post*, July 28, 1923.

during the early days of the first five months of the fiscal year, can be wholly overcome. Immigration officials in Washington and New York sufficiently answered the ambassador's criticisms. The United States is doing its utmost to keep the island clean and sanitary, and to treat arriving immigrants humanely. Any one who thinks this an easy task should spend several days at Ellis Island during the time of congestion. The trouble is chiefly with the aliens themselves, many of whom have not the remotest conception of cleanliness or of common decency, as Anglo-Saxons understand those terms. The keynote of Ambassador Geddes's report is contained in the following concluding sentence: "What Ellis Island needs, in my judgment, is to be relieved of the presence of about one half of the people who are poured into it." Americans seeking an improvement in the conditions of immigration may well take those words to heart.

What the Percentage Immigration Law has Accomplished

The three per cent. law is not perfect, but it has on the whole worked successfully and has fully justified its enactment. Without it, our immigration during the past two years would surely have amounted to between two and three millions a year, and 80 per cent. or more would have come from southern and eastern Europe. For a good many years before the war, aliens from southern and eastern Europe very largely outnumbered those from northern and western Europe. Under the law, the numbers are about equalized. There is absolutely no doubt that this limitation upon the numbers of southeastern European immigrants has greatly stimulated immigration from northwestern Europe. As long as immigration from southeastern Europe was unlimited, people from northwestern Europe did not come here in large numbers for the reason that they did not want to compete with hordes of ignorant and unskilled aliens who are contented with low wages, low standards of living and frequently intolerable working conditions. The situation has now completely changed. Since the United States has placed a definite limit to the numbers who can come from southeastern Europe, immigration from northwestern Europe has taken a distinct spurt, and there has been a steady increase in the numbers of the better-class northern and western Europeans who are coming here. The quota law is accomplishing just what its advocates predicted, and there are few outside the ranks of the hyphenates who do not realize that this is a very distinct gain for the country.

Not only so. The number of native-born workers in many of the better-paid occupations in this country is increasing because of the decreased competition with newly-arrived aliens of the lower grades. This trek of native-born into jobs on which aliens have

been employed proves the soundness of the position long maintained by unprejudiced students of our immigration problems. There are no jobs which "native labor" will not do, provided the pay is sufficient to support a self-respecting American workman according to American standards of living. As the late General Francis A. Walker used to say, there is no job too "mean" for a self-respecting American to do. It is the low-grade man who makes the mean job. Until ignorant and unskilled foreigners came to the United States, nothing was said about "mean jobs which native Americans refuse to do." It is chiefly because they do not wish to associate and compete with the lower grades of newly-arrived aliens that young Americans who graduate from our public schools disdain manual labor which, because it is so largely performed by aliens, is considered degrading. There is a very vicious circle here. The greater the inflow of "cheap" immigrants, the less will young Americans want to compete with them in manual occupations, and then the more immigration will be needed to do these jobs The continued importation of great hordes of ignorant aliens would still further degrade manual occupations, and still further interfere with the development of a high class of native workmen. Further, now that a vast amount of hard manual labor can be done by machinery, there is far less need than there used to be for a huge supply of crude labor. The quota law, which has reduced the numbers of common hand laborers from southeastern Europe, has brought us an increasing number of intelligent skilled northern Europeans, who already know how to manage machines, or who can easily be taught the use of American labor-saving machinery.

Suggestions for New Legislation

Americans have been doing a good deal of serious thinking on the question of their future immigration policy. It is a difficult problem, but public opinion seems to be crystallizing around these three points: (1) Never again is there to be an unlimited inflow of cheap alien labor; (2) a numerical limitation of immigration is here to stay; (3) there must be a careful selection of our immigrants within the fixed limits. To accomplish these ends we should have (1) percentage limitation; (2) based on the census of 1890, and (3) some form of overseas inspection. The conviction that the census of 1890 should be used as the basis of any percentage law has been growing rapidly all over the country. Since there were fewer southeastern Europeans here in 1890 than in 1910, a percentage provision based on the former census would decidedly cut down the numbers of immigrants from that area. The great majority of our people are opposed to the continued inflow of low-grade unskilled foreign labor and are in favor of the immigration of skilled labor. This provision would accomplish both objects. It would change the

character of immigration, and hence of our future population, by bringing about a preponderance of immigration of the stock which originally settled this country and which still makes up the bulk of our population but can not continue to do so without such legislation. It can not be denied that on the whole immigrants from northwestern Europe furnish us the best material for American citizenship and for the future upbuilding of the American race; that they have higher living standards than the bulk of southeastern Europeans; are more homogeneous; of a higher grade of intelligence; better educated; more skilled; better able to understand, appreciate and support our form of government. A percentage limitation based on the 1890 census offers a simple, practical solution of many of our immigration problems, and is sound American policy, based on historical facts. Unprejudiced observers of recent immigration are agreed that the bulk of the aliens who have been coming here from the countries of northern and western Europe are good types, able-bodied, physically fit, independent, paying their own passages, many of them farmers and skilled workmen, and avoiding the congested districts of a few large cities. Southern and eastern Europe, on the other hand, have been sending large numbers of peddlers, sweat-shop workers, fruit-stand keepers, bootblacks and the like, mostly non-essential members of the community, and flocking to the centers of densest population.

The country at large has been greatly impressed by the results of the army intelligence tests made during the war, which have been thoroughly analyzed by Lieutenant-Colonel R. M. Yerkes, Dr. C. C. Brigham and others. The generally higher intelligence of our recent immigrants from northern and western Europe is definitely established, as is the fact that the immigrants who have been coming during the past few decades, mostly southern and eastern Europeans, have been steadily deteriorating in intelligence. The men who have analyzed the statistics have made careful tests of the tests themselves, and are convinced "that the responses to the tests reveal only innate intelligence and not acquired information and education" This answers the argument that the drafted men who were natives of northwestern European countries, most of whom had been in the United States for some time, were better able to profit by the benefits of American environment and educational facilities, and hence were at an advantage as compared with the more recently arrived recruits from southeastern Europe.

There are many people to whom intelligence tests do not appeal, or who more or less distrust them. To such the "pocket-book argument" comes a good deal closer. Dr. H. H. Laughlin has recently made a very thorough investigation of the "socially inadequate" groups in 445 state institutions. His report should be carefully

studied by every American. Of the institutional population thus studied, 44 per cent. was either of foreign birth or had one or both parents foreign-born. The states whose public institutions were examined are devoting on an average nearly eight per cent. of their total expenditures to the care and support of the inmates of foreign birth or parentage. In many states the expense is much greater. The State of New York in a recent year was spending over $4,000,000 for the care of insane aliens in civil hospitals. It should be remembered that these figures take no account of the foreign socially inadequate in private institutions, or supported by private charity outside of institutions. Dr. Laughlin's studies bring out another very striking and important fact, *viz.*, that immigrants from northwestern Europe contribute far less in proportion to our alien socially inadequate institutional population than do those from southeastern Europe. A percentage limitation based on the census of 1890 would therefore not only reduce (1) the inflow of unskilled "cheap" labor, but would also greatly reduce (2) the number of immigrants of the lower grades of intelligence and (3) of immigrants who are making excessive contribution to our feeble-minded, insane, criminal and other socially inadequate classes. Such a provision is the simplest, most logical and most effective means readily at hand for accomplishing all three of these very necessary things.

American public opinion is also firmly convinced of the need of (1) a far more effective system of inspection at our own ports, and of (2) some sort of preliminary selection overseas. The former requires larger appropriations and more and better paid inspectors, both general and medical. The latter has for years been advocated as necessary and humane—a benefit to the United States and a means of preventing unnecessary hardship to the alien. There have always been many and serious difficulties in the way of our establishing a complete and thorough system of foreign inspection: the expense; the need of a very large number of medical and other officials; the great opportunities for graft and corruption if natives of other countries are employed abroad as clerks, interpreters, and the like; the objections of certain foreign governments to our making a selection of prospective immigrants on their own territory. In spite of these obstacles, it has seemed that by means of a little skilled diplomacy it might be possible to bring about at least some sort of preliminary selection abroad. For example, definite assurance on the part of a foreign government that all intending immigrants had been examined and found eligible under our immigration laws, and that they belonged to the classes of aliens desired by us, might make our own inspection overseas unnecessary (we must always have inspection at our ports of landing in any case), and

would satisfy any question of international relations. During the past summer Secretary of Labor Davis has been abroad studying the possibilities of a plan for having prospective immigrants examined in their own countries, and according to press despatches he has in preparation a new immigration bill embodying the features of examination abroad and registration of all aliens entering this country. If Secretary Davis has been able to bring about any such working plan with foreign governments he will have made one of the most important possible contributions towards the settlement of our immigration problem. What Secretary Davis is seeking is "not a foreign policy, dictated by foreign steamship companies, but an American policy, formulated by and in the interests of the United States." With that point of view all Americans will surely agree.

Scientific Studies of Immigration

Our immigration policy in the past has been too much a matter of temporary economic or political expediency. One of the most encouraging recent developments is the rapidly growing conviction on the part of our people that, as Dr. H. H. Laughlin has admirably stated it, "immigration is a long-time investment in family stocks rather than a short-time investment in productive labor." Many of the leading scientific men in the United States are now making a study of the problem in order to ascertain, by careful scientific methods, the facts which may be useful in guiding future legislative action. These men have no political or sociological axes to grind, and are wholly unprejudiced. At least two organized scientific bodies are now at work on the matter. The National Research Council has appointed a committee of experts in anthropology and psychology, as well as in vital statistics, heredity and the influences of environment. This committee is already at work. Further, the newly organized Eugenics Society of the United States has decided to begin its labors with chief emphasis on three subjects, one of which is "working out and enacting a selective immigration law." There is no doubt whatever that the results of these scientific studies will be of the utmost importance in our future immigration legislation Experts have already told us that had mental tests been in operation, and had the "inferior" and "very inferior" immigrants been refused admission to the United States, over 6,000,000 aliens now living in this country, free to vote, and to become the fathers and mothers of future Americans, would never have been admitted. Now that the facts are known, the American people are not going to stand for any such degradation of American citizenship, and any such wrecking of the future American race.

THE BLACK WIDOW: ITS LIFE HISTORY AND THE EFFECTS OF THE POISON

By W. J. BAERG
UNIVERSITY OF ARKANSAS

THE Black Widow, *Latrodectus mactans*, and the tarantula are the two species of spiders of Boreal America that many arachnologists and medical entomologists regard as dangerously poisonous. The Black Widow is a small black spider; its abdomen is nearly globular, shiny black above and with a dark red hour glass figure below. The cephalothorax (head and thorax) is very small in comparison with the abdomen. The female spider is about one half inch in length. The male is about half the size of the female. It has a red stripe along the middle of the back, and may have a series of stripes on the sides of the abdomen.

The Black Widow is frequently mentioned in scientific literature The genus seems to be cosmopolitan, and all the known species apparently enjoy a reputation similar to that of our *L. mactans*. Recently there have been a number of shorter articles in *Science* and other journals reporting cases of poisoning attributed to the Black Widow. These cases are quite like the ones cited in text-books of medical entomology; they are based on circumstantial evidence, and the reported effects vary all the way from a slight indisposition to death.

In America the Black Widow is not so well known to the general public as it is in some other countries. In Southern Russia, where *L. erebus* occurs, it is greatly feared by the natives. When this spider seems at all common, children and older persons are employed to search the fields and meadows and kill the dreaded spiders. At such times the men and women working in the field are advised to be provided with a piece of a raw onion, which, in case of a spider bite, is rubbed over the bitten place and is said to prevent serious consequences.

The species of *Latrodectus* occurring in Madagascar, New Zealand and elsewhere are likewise generally known to the natives and universally feared.

With reference to occurrence in Southern Russia, I am told that it is commonly believed that the Black Widow is present in considerable numbers only during dry seasons. This is possibly due to the fact that during such times the spiders may be forced to search for water, and on their wanderings they are more commonly seen.

In the Ozark region of Arkansas the Black Widow may be commonly found under stones. During normal seasons, it may be anywhere under stones that are not often disturbed. During a dry season these spiders seek shelter under stones in a dry creek bed or near a stream. At such a time they are also commonly found in the housing of water meters and probably also in basements of houses. Although they are very common in this region, they are here apparently not known as being more dangerous than other spiders. Many of the physicians know the Black Widow and have reported to me cases of poisoning presumably caused by this spider.

Life History and Habits. As already indicated, the Black Widow is most commonly found under stones. At about the middle of June, the females may be found, sometimes three or four under one stone, with their egg sacs or cocoons. Whether the females actually become sociable at this time, so as to seek each other's company or whether they merely exhibit such tolerance towards each other, in case they meet, is not settled. McCook believes that the latter is true with many spiders I am inclined to think that the Black Widows actually become sociable in a degree at the time of egg laying. I found three females with three egg sacs under one stone, and another female with one egg sac under another stone near by. A careful search of several acres of ground in the vicinity failed to bring any additional spiders.

In this latitude the female constructs, in one season, as many as four cocoons; at the rate of about one every two weeks. Each cocoon holds about 300 eggs. The young spiderlings leave the cocoon about ten days after the eggs have been laid. In nature I have not observed any young; but I have reared them in the laboratory, placing from four to six cocoons in each of a number of quart jars. The young spiders feed on their brothers and sisters, even if flies and young grasshoppers are provided. Whether or not the same is true in nature, I can not say definitely; but I rather believe that it is.

When reared as just described, the females attain full growth in about two months. The males develop more slowly, and they are rather difficult to rear. In a jar where about 1,200 to 1,500 young spiderlings hatched, there were left, after five weeks, one nearly full-grown female and one half-grown male. In another jar having about the same number of young spiders, four females attained about half of their growth. Later, only one of these survived.

In nature the males are apparently very scarce during midsummer, while early in fall the young males, two thirds to full grown, may be found as commonly as the females. Apparently, most of the old females die at the end of the summer or during fall,

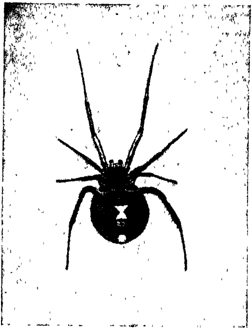


FIG. 1. Ventral aspect of *Latrodectus mactans*, female. Magnified three times.

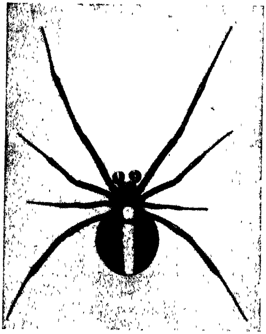


FIG. 2. *Latrodectus mactans*, male. Magnified four and a half times.

although some of them may live through the winter, if I may judge by observations made in the laboratory. Of three females that were taken in June, two died early in fall. The third lived till January 10.

An informant from Southern Russia says that *L erebus* is not shy and frightened by any disturbance, as are practically all the spiders. In the behavior of our own species, there is all the timidity and shyness common to most of the other Arachnida.

The Effect of the Poison. Arachnologists apparently do not regard the Black Widow as dangerous as the tarantula. Professor Comstock says in regard to the genus Latrodectus: "They are feared wherever they occur and it is quite possible that they are more venomous than other spiders." Of the tarantula, although he knows of no authenticated case of a person being bitten by one, he says, "I should not like to be bitten by one of the larger tarantulas."

James H. Emerton says of the Black Widow: "It is everywhere feared as poisonous and dangerous; probably on account of its large size and conspicuous colors, as there is no good reason for considering it more poisonous than other spiders." Mr. Emerton does not mention the tarantula in his book.

Henry C. McCook says of the Black Widow: "It must be confessed that the experiments of naturalists, as well as their observations, are unfavorable to the popular belief in the dangerous character of the spider's stroke, except in the case of the very large species, such as our American tarantula. Tarantulas with such large fangs and supply of poison are regarded as dangerous and should be handled with great care."

Mr. M Lucas, an eminent arachnologist, states that he has been bitten repeatedly by the New Zealand species of *Latrodectus* and has not observed any ill effects.

Medical entomologists are agreed on the dangerous character of the Black Widow. Presumably this is because they have accepted the circumstantial evidence given by medical practitioners, conflicting as it is.

There is, so far as I know, not one well-authenticated record giving reliable information on the effects of the bite of the Black Widow. In all recorded cases, the identification of the spider is based on information given by the patient.

Dr. Rudolph Kobert attempted some tests with the bite of the European species of *Latrodectus*, but was unable to induce the spiders to bite the animals intended for experimentation. He then proceeded to make extracts of the cephalothorax of dried specimens in distilled water or physiological salt solution. Three cubic centi-

meters of the extract, containing 4.39 mg. of the organic material, were injected into a cat of average size. Complete paralysis developed in a short time and in twenty-eight minutes the cat was dead. The extract was injected also into rats, dogs, squirrels, sparrows, etc., and in all cases caused paralysis, followed by death.

Significant as these results are they do not give any information in regard to the effects of the bite. Neither are they entirely reliable in regard to the nature of the poison. An extract prepared from dried specimens, treated with salt solution, exposed to various temperatures, etc , can not be regarded as identical with the poison poured out through the fangs.

Dr. Marx made a similar study of the poison of *Latrodectus mactans*. He prepared an extract of the poison, injected it into guinea pigs and rabbits, but was unable to observe any definite symptoms.

Since there are but two spiders in Boreal America that are by medical entomologists and others regarded as dangerous, and since I had some time ago been able to satisfy my curiosity in regard to the poisonous nature of the tarantula,[1] I decided to make some tests with the other poisonous spider, the Black Widow.

The opportunity for these tests came last summer, late in June, when I found four full-grown females with their cocoons. By feeding them each a nymph of a meadow grasshopper once in five to six days, they were easily kept in an apparently normal condition.

The Effect of the Poison on Rats. For preliminary tests, white rats about four weeks old were used. The difficulty that several investigators have met, when trying to induce the spiders to bite, was overcome by feeding the spiders about forty-eight hours before the tests were to be made. Although, by observing this rule, all our attempts to induce the spiders to bite met with success, yet it seems very doubtful that this is the real or only reason for the results. By making a considerable number of tests one obviously acquires some little ability in holding the spiders properly, and this is perhaps more important in getting the desired response from the spiders than is the particular day of feeding.

The rats were prepared for the test by clipping off the hairs on the inside of the left hind leg. Two rats and two spiders were used in the first test. The spiders bit well and the fangs were allowed to remain inserted for several seconds.

In a short time both rats presented distinct symptoms of illness. They humped up, turning the head underneath till the face rested on the floor of the cage; from time to time they would jerk forwards as if in convulsions. The eyes were usually closed and the rats

[1] This Journal, May, 1922.

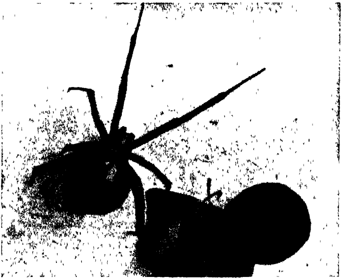


FIG. 3. Black Widow and cocoon. Magnified two times.

were not easily aroused. When walking they were very unsteady and stumbled frequently. These effects lasted from six to ten hours, when the rats rapidly recovered and behaved in an entirely normal manner. To confirm these observations the test was repeated, applying the same spiders to the same rats. The symptoms were very similar to those following the first test, but markedly milder.

Since these effects of the bite were relatively insignificant, it seemed desirable to compare them with the effects of the bite of a supposedly harmless spider. For this, I used a funnel web weaver, *Agalena naevia*, which is very common in this region. The funnel web weaver is admirably adapted for such tests. It is easily held and it bites as soon as its fangs come near enough anything they can penetrate.

Two young white rats were used for this test. For about thirty minutes following the bite, they appeared slightly affected; they sat somewhat humped up with eyes partly closed; then they proceeded to walk around, using the wounded leg freely, and otherwise behaved in an entirely normal manner.

The contrast between these symptoms and those following the bite of the Black Widow is very apparent. It is obvious that if the funnel web weaver injected any poison, which it probably did, this is quite innocuous. A question that has been raised by various workers is whether the Black Widow has relatively large poison glands or not. Dr. Marx reports that the glands of *L. mactans* are

relatively small. Bordas describes the poison glands of the European species, *L. guttatus*, as much larger than those of other spiders. Riley and Johannsen are convinced that the same is true of our American species of *Latrodectus*. It seems unfortunate that the names of "the other spiders" are not given.

The following measurements of the glands of the Black Widow and of those of the funnel web weaver, in connection with the accompanying figures, may help to clear up this question. The glands of *Latrodectus* vary greatly in size, especially in length. The longest glands found in dissecting six specimens measured 3.5 mm; the shortest 1.75 mm. (These two were used for the illustrations

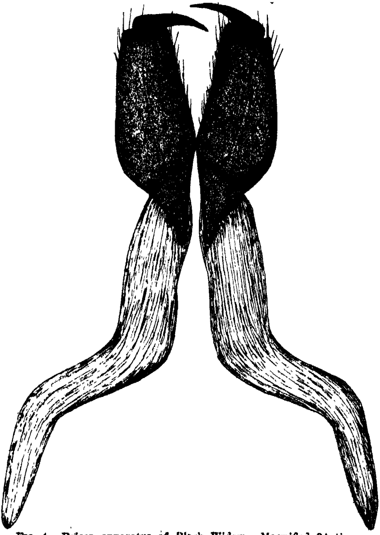


FIG. 4. Poison apparatus of Black Widow. Magnified 34 times.

of Figs. 4 and 5.) An average length is between 2 and 2.5 mm. The average width of the glands,—and this does not vary appreciably,—is .37 mm to .50 mm.

The glands of the funnel web weaver, from a study of a half a dozen specimens, were found to measure between 2.75 mm to 4.25 mm. in length, and 1.0 mm at the greatest width.

The glands of the male *Latrodectus* were studied in but one specimen. As the figure (8) shows, they resemble essentially those of the female. They measured .99 mm in length and .17 mm at the greatest width.

Even from this restricted study of the size of the glands, thus much may perhaps be said. The size of the glands is not a significant feature, in so far as a comparison between the Black Widow and the funnel web weaver is concerned. The gland of the male *Latrodectus*, as will be shown later in this paper, is no indication as to the dangerous or harmless nature of it.

Acquired Immunity. In view of the fact that the rats exhibited milder effects after the second test than they did after the first, it seemed well to make additional tests and determine how readily the animals became immune to the effects of the poison. The same rats that were used in the tests described in the preceding paragraphs were used here. When these rats had been bitten for the third time, they showed rather slight effects of poisoning. After the fourth time, the rats showed no other response than licking the bitten leg. These tests were made at intervals of one week. A degree of immunity that is well-nigh perfect is thus acquired by the rats when they have received three rather large doses of the poison.

Does the Poison persist throughout the Year? L. E. Walbum, in working with extract prepared from *Epeira diadema*, found that the Epeiratoxin (the principle in the poison that is apparently fatal to warm-blooded animals) is present in the females only during a part of August and during September. The presence of the toxin coincided with the development of eggs in the fecundated females. His tests showed also that the males of this species did not possess any appreciable amount of the toxin.

To determine whether or not the Black Widow retains its poisonous properties during the winter (or throughout the year) tests with an old female and a young full-grown female were made on November 26 and December 3. Although these spiders had been kept in an unheated room with windows always open, and seemingly had ceased feeding with the advent of cool weather in late October, yet they were rather easily induced to bite the rats.

The symptoms following the bite were very similar to those observed in the summer and showed clearly that the spiders retain

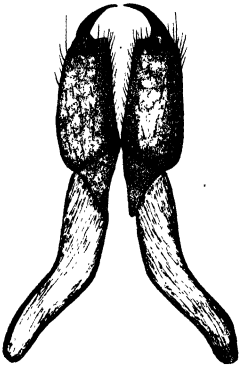


FIG. 5. Poison apparatus of Black Widow. Magnified 34 times.

FIG. 6. Fang of Black Widow, showing poison duct and teeth. Magnified 132 times.

their poison during the winter. The effect of the poison is the same in winter as it is in summer.

The Effect of the Bite on Man. On July 9, at the time when the second test was made on the two white rats, I decided to use a third spider on myself. The first attempt to induce it to bite practically failed. After much coaxing it finally made a very feeble effort and just pierced the skin of the inside of the third finger. The sensation produced by the fangs piercing the skin was barely noticeable. Later this spot was at times covered with profuse perspiration. No other significant symptoms were observed.

On the following day the test was again attempted. This time the spider bit freely and well. Since on the previous day no symptoms had appeared, the spider was allowed to keep the fangs inserted for about five seconds. From the point of view of the experimenter, the results were all that could be desired; from the subject's point of view, they were slightly severe.

The test was made at 8:25 A. M. The sensation produced by the fangs penetrating the skin was rather slight; but gradually, as the poison was injected, the sensation became painful, sharp and piercing. The area near the bite, immediately after the poison had been injected, at first turned white (as after a bee sting), but in a short time became very red. A very slight swelling appeared. In about fifteen minutes an aching pain developed in the tendons of the left shoulder. In a half an hour, the arm felt lame and the aching was more marked.

By 10:25 the pain in the left hand was very severe, a sharp burning sensation, and the pain in the muscles had extended to the chest. Some time later it appeared in the muscles of the hips. At eleven o'clock some dilute ammonia was applied to the left hand; but failed to produce any results. At this time the aching pain extended into the legs. At 12:20 I had seen a doctor and on his advice went to bed. At this time the pain in the hips was very severe, the chest felt cramped; breathing and speech were rather forced and irregular.

In view of the rapidly developing symptoms, it seemed best to go to the hospital. This I did at 5:30 in the evening. A hot bath that I took soon after coming to the hospital gave very appreciable results. The diaphragm was entirely relieved, and the aching pain, now felt in almost all the muscles of the body, was temporarily lessened. Unfortunately, a dressing soaked with a solution of $KMNO_4$, placed on the left hand by my physician, prevented me from holding this hand in the hot water.

During the night a desperate attempt was made to draw some of the poison from out of my hand. The $KMNO_4$ solution was renewed frequently and an electric oven, as hot as I could bear, was placed over my hand. This was left on for an hour or two, and then kept off an hour. The effort was all in vain, and incidentally caused much pain. At four A. M. I rebelled and it was discontinued. Obviously, I did not sleep at all; in fact, I did not lie still for much longer than thirty seconds at a time. Rolling about in bed seemed to ease the pain a bit.

In the morning after a hot bath, at which the left hand got a generous share, all pain was considerably relieved; in fact for a half an hour or so, I felt scarcely any pain. On the evening of this

day, I made the first attempt to eat, partaking of some oyster soup with much relish.

Another hot bath in the evening made me think that I had practically recovered. This was a mistake; though I slept for short periods, I was so delirious that as soon as I would doze I would be frantically and in an utterly aimless fashion working with—spiders. Truly a state of: "Die ich rief, die Geister; Werd'ich nun nicht los."

A hot bath the following morning brought the usual improvement. During the day I slept for short periods and spent most of the day reading.[3]

The following night brought the much desired sleep; there was some dreaming, but of quite innocent affairs. On the next day (July 13) I went back to work. A feeling of wretchedness was more or less in evidence, but this did not seriously interfere.

From the hospital record I learned that a slight fever, one to two degrees, was present in the afternoon and evening of the days I spent in the hospital. Later, I took a number of readings of my temperature each day and found that it kept fluctuating from 96 or 97 to 99 or 99½. Whatever may have caused this variation in temperature, it did not have any appreciable effect on my general condition. On the day after I left the hospital, I was again in the best of health, with a good appetite and usual vigor.

The experience had some unpleasant features in it; yet it had also its attractive features. The symptoms were all new to me, and each change presented a surprise. The unpleasant features were many times compensated for by the fact that I had satisfied my curiosity regarding *the other* of the two poisonous spiders of America.

The Poison of the Male Spiders The question as to whether the male of *Latrodectus mactans* (Black Widower?) is able to inflict injuries similar to those attributed to the female has apparently not received any consideration. Walbum, as already noted above, found that the males of *Epeira diadema* did not possess any appreciable amount of the toxin.

The glands of the male, as may be inferred from the illustration and the measurements given on a preceding page, are, in proportion to the size of the male, about as large as are those of the female.

[3] In selecting the reading matter for this trip to the hospital, I had used too little care. It was Cytherea, by Hergesheimer. While I do not wish to invade here the field of literary criticism, yet the reading formed a part of this experiment, and the effect should be given. It was nearly as unpleasant as the effects of the spider poison.

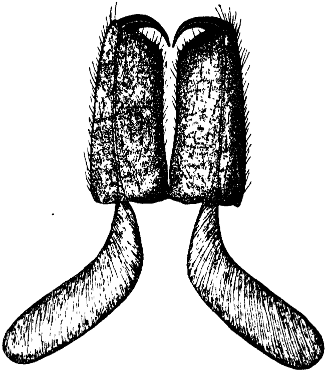


FIG. 7. Poison apparatus of a Funnel Web Weaver. Magnified 17 times.

FIG. 8. Poison apparatus of *Latrodectus mactans*, male. Magnified 34 times.

An attempt to determine the effects of the bite of the male on rats was made on November 26 and December 3. The test was conducted essentially like those made with the female spiders. The first difficulty that presented itself was that the male is not so easily held because of its small size. Furthermore, its fangs are rather small, and are entirely hidden behind the large bulbs of the palpi. By the use of a binocular loupe, magnifying about four times and a small camel's hair brush, the latter difficulty is largely overcome. The male is a timid and diffident creature; no amount of teasing or persuasion would induce him to bite. He either could not or would not bite. Thinking that even the short hairs (on the inside of the leg of the rat) were in his way, I tried to induce him to bite on the inside of my small finger. This, too, was in vain. All the response that he made was an indifferent nibbling.

The evidence in regard to the poisonous properties of the male *Latrodectus* is therefore left incomplete, and far from conclusive. The presence and the size of the glands indicates that the male is poisonous; but his actions indicate that he uses the fangs only for seizing prey and is therefore entirely harmless.

PETROLEUM

By Professor MARSHALL HANEY
SHENANDOAH INSTITUTE

Introduction

Petroleum is absolutely necessary to the age in which we live and one of the most important substances used by society to-day.

Cotton, steel and coal are of vast importance to us, but they can not compare in importance with petroleum, the only source from which lubricants can be obtained in sufficient quantity to smooth the wheels of industries.

Without lubricants the railroads could not operate, nor could steamships sail the seas. No industrial plant could run its machinery, and the crops on the farm would have to rot where they grew, because the wheels of the humble farm wagon must be lubricated, while the farm's motor truck must have gasoline and lubricating oil. Petroleum is also the sole source of gasoline and, in addition, it provides kerosene. Statistics show that 95 per cent. of the world's population uses kerosene as an illuminant. In large cities only 25 per cent. of the total of the houses are lighted by electricity, and electricity could not be produced unless the bearings of the engines and generators in power plants of central stations were generously supplied with lubricating oil. Fuel oil, one of the products of petroleum, is a vital necessity for ships of the navy which protect our shores, and our new merchant marine uses it as a fuel.

Historical Outline

All the early races which inhabited the earth knew of petroleum and used it. The word itself is made of two Latin words, *petra* (rock) and *oleum* (oil). It means rock oil. Its first use is lost in the darkness of antiquity, but we know that the builders of Babylon used asphaltum, a residue of petroleum, to bind together the rocks from which the city was built. The Babylonians secured the asphalt from the fountain Is on the Euphrates, and this fountain attracted the attention of the early emperors Alexander, Trajan and Julian. Herodotus describes a spring on the island of Zante from which the Egyptians obtained a supply of the same substance used in preparing their mummies.

The Greek historian Descorides Pedaners tells us that the citizens of Agrigentum in Sicily burned petroleum in lamps long before the birth of Christ. The Persians for centuries burned it in

their lamps, and the Hindus in India used it as a preserver of timber and in the cremation of corpses. The Incas in Peru and the Aztecs in Mexico used asphalt for architectural purposes. The first settlers of Pennsylvania found the Indians using petroleum as a medicine, as a paint when mixed with bright red and yellow mineral earths and as a timber preservative.

Three miles above Oil City, Pennsylvania, there was a remarkable oil spring in the middle of Oil Creek. From the rocks and gravels in the creek bed oil would rise in large globules and would spread over the surface of the waters. Nathaniel Carey dug and walled shallow holes in the creek bed, and as the oil rose on the still water in these pits it was collected by skimming and sold as "Seneca Oil" for 25 cents a gill. In all probability this was the first sale of crude petroleum in the United States. Before this time the white settlers followed the Indian custom of collecting oil by spreading blankets on the springs, allowing the blankets to become soaked with oil and then wringing them out.

The early settlers secured their salt from brine pumped from wells. These brines in West Virginia, Kentucky, Tennessee and Pennsylvania were contaminated with petroleum Samuel Kier, a druggist of Pittsburgh, whose father worked some of the salt wells on the Allegheny River, knew of the medicinal value of the oil and succeeded in working up a large trade in "Kier's Petroleum," selling two barrels a day at $1.00 per pint. For illumination our forefathers had been using beeswax, tallow, candles or sperm oil. The heavy smoke and strong odor rendered petroleum at first unfit for an illuminant. In 1846 Dr. Abraham Gesner discovered a new illuminant made by distilling coal, obtaining an oil he called kerosene or carbon oil, and it was popularly called "coal oil"; even in recent years we hear kerosene called "coal oil."

Dr. Gesner patented his distilling process in 1854, and his new illuminant sprang immediately into favor and was so much more in favor than fish oil that it practically destroyed the fish-oil industry. The demand was so great that the refineries could not produce this oil fast enough to meet the demand, and the price rapidly advanced to two dollars a gallon.

It was generally believed at this time that petroleum contained an illuminant identical with "carbon oil," which led to attempts to distil it.

Samuel Kier, experimenting in 1848 with a kettle and wooden coil, succeeded in obtaining from petroleum a product which he sold as carbon oil for $1.50 a gallon.

James Young, of Scotland, patented a process for obtaining paraffin wax from petroleum by distillation, and in 1853 Aaron

Robbins, of Meadville, Pennsylvania, developed a still having a capacity of a barrel of crude oil a day, which was soon enlarged to a capacity of 100 barrels of petroleum per day The only product Robbins made an attempt to save was the burning oil, which he called headlight oil, and the petroleum he used was imported from Canada

Twelve barrels of carbon oil obtained from petroleum were shipped from Pennsylvania to New York in 1857, and this shipment created a great demand for petroleum

Prior to the year 1858 there had been many attempts to dig wells with pick and shovel down to bedrock which, at that time, was considered to be the source of petroleum. Prior to 1859 nobody had succeeded in reaching bedrock with an open well Edwin Drake tried to dig a well through the clay and quicksand near the oil spring. He finally succeeded by driving a pipe to bedrock and then removing the material from the pipe and then continued to drive into the bedrock until he reached a depth of 69 feet from the surface on August 27, 1859, and this well produced twenty barrels per day.

Drake's method of sinking wells was immediately adopted, and many other wells were sunk as soon as his success was known. The oil obtained from these wells was stored in whiskey barrels containing 42 gallons, and this unit of measure has been retained.

Periods in the Industry

The use of petroleum as an illuminant started in 1859, and for many years afterward kerosene was the only product sought. By the summer of 1861 the production of petroleum had increased to 1,500 barrels per day, and by the early part of 1863 it had increased to 15,000 barrels per day. During the period of the Civil War production declined.

With the introduction of automobiles a demand for gasoline was created, and at the present time the demand for this material, which was once regarded as waste, has become more important than kerosene. The period from 1909 to date may properly be called a gasoline period, and at the present increase in the use of fuel oil it appears as if we might be entering a fuel oil period.

Barrels of Petroleum marketed in U. S. from 1859 to 1920

1859	2,000 barrels
1869	4,215,000 "
1879	19,914,000 "
1889	35,163,000 "
1899	57,070,000 "
1909	183,170,000 "
1919	375,559,000 "
1920	443,402,000 "

The above table shows the rapid increase per year in intervals of 10 years.

OIL FIELDS IN THE UNITED STATES

There are seven oil-producing areas in the United States which, described in their order of original discovery, are as follows:

The Appalachian Field: The pools in this field have never been abandoned or exhausted, and there are producing wells to-day close to Drake's original well. This field extends along the western slope of the Allegheny Mountains and includes Pennsylvania, Ohio, New York, West Virginia, Kentucky and Tennessee. The development in this field began in 1859; it reached its maximum production in 1900, producing 36,000,000 barrels, and in 1920 it produced 30,511,000 barrels.

The Mid-Continent Field is the most important oil field of to-day. It includes Kansas, Oklahoma, central and northern Texas and northern Louisiana. The maximum production was 249,074,000 barrels in 1920.

The Lima-Indiana was opened in 1884 in Ohio, and the maximum production was 25,000,000 barrels in 1896, and in 1920 it produced 3,059,000 barrels.

The California Field was discovered in 1899, and the oil in this field was originally used for fuel because it contained very little gasoline and kerosene, but in recent years deep drilling has produced a high grade oil. In 1920 its production was 105,668,000 barrels.

The Gulf Field includes many pools in southern Texas and Louisiana. It became prominent in 1901 and reached its maximum production of 36,000,000 barrels in 1908 and in 1920 it produced 26,801,000 barrels

The Illinois Field consists of many scattered pools in the state of Illinois. Important developments began in 1905. The maximum production of the field was 36,000,000 barrels of oil in 1908, and in 1920 it produced 10,772,000 barrels.

The Rocky Mountain Field is located on the eastern slopes of the Rocky Mountains in Wyoming, Montana and Colorado. The maximum production of this field was about 140,000,000 barrels in 1920.

The rank of the fields in 1920 with respect to the quantity of oil produced was:

Mid-Continent	249,074,000	barrels
California	105,668,000	"
Appalachian	30,511,000	"
Gulf Coast	26,801,000	"
Rocky Mountain	17,517,000	"
Illinois	10,772,000	"
Lima-Indiana	3,059,000	"

Until 1885 the Pennsylvania field produced more than 98 per cent. of the world's supply of petroleum. The Russian production began to be commercially important in 1869 and by 1892 it exceeded the production of the United States, reaching its highest point in 1901. The United States forged ahead in production, however, until we now produce 64 per cent. of the world's total. Mexico's production grew rapidly and to-day it ranks next to the United States.

Climate

The climates of the past are of prime importance in the development of abundant life and consequently would be among the determining factors in the distribution of the petroliferous areas. To have petroleum there must be a source and, since living matter is considered the source of petroleum, geological conditions must have been such that living organisms were abundant. The arid regions have not given rise to living things in sufficient quantity to produce oil; also the same is true in cold regions and inbound lakes. To produce an abundance of living organisms warm, moist conditions must prevail.

Before an area could be considered a petroliferous province, it must have had an abundance of living things from which the oil was formed. By studying the earth's surface one will be impressed with the fact that all the important oil fields lie between 20° and 50° north latitude and of course are restricted to this range of climate.

The Origin of Petroleum

The probable origin of petroleum in the earth has given rise to much discussion It has been found by laboratory experiments that hydro-carbons may be obtained from organic substances and, likewise, from certain of the inorganic substances. From fish oil, hydro-carbons which are similar to those obtained from the earth have been obtained by destructive distillation. Wood and vegetable oils have been shown to yield hydro-carbons. From cast iron spiegeleisen and ferro-manganese, when dissolved in a mineral acid such as hydrochloric, there is evolved hydrogen and small quantities of hydro-carbons. It is a matter of common knowledge that most carbons react with water to form hydro-carbons.

The theories as to the origin of petroleum in nature that have been proposed may be divided into those that ascribe their origin to inorganic substances and those that recognize an organic source for petroleum. The inorganic theories are diverse, but the best known involve an assumption of the existence of carbides deep within the earth, from which hydro-carbons are formed.

The organic theories are those which ascribe the origin of petroleum to animal sources, those that ascribe the origin to vegetable sources, and those that ascribe the origin to vegetable and animal sources combined. The theory of origin from animal sources maintains that the petroleum originates from the slow decomposition of the fatty substances of animals imbedded in the rocks. Those who regard petroleum as derived from vegetable matter for the most part name the lower plants as the probable source, including the cellular marine. Those who recognize that the petroleum oils may be derived in part from animal remains and in part from vegetable substance sources are in majority at the present time.

The geologic relations of petroleum deposits supports the organic theory of its origin. The diversity of the petroleums and the varying kinds of sedimentary rocks with which it is associated argues for the probable derivation in some instances from animal remains and at other places from plant remains, or, in other instances, from animals and plants imbedded as they often are in the same formation.

In the application of geology of the location of petroleum deposits, the organic theory of origin is very generally applied, and deposits high in the organic matter are universally sought as one of the conditions favorable to the accumulation of oil in commercial quantities.

The Accumulation of Oil Gas into Deposits of Commercial Value

At first, the organic materials in the rocks were widely disseminated, while the oil as found in nature is usually segregated into restricted areas.

Migration of Oil

It is a generally accepted conclusion that oil and gas as obtained commercially have migrated more or less from the original source. The forces that influence migration include specific gravity, capillary attraction, perhaps some others not fully understood. The well-known difference in specific gravity between oil, gas and water are among the important causes of the separation of oil, water and gas.

As oil is lighter than water it naturally rises to the top and hence tends to segregate in the rock above the water line. Gas naturally tends to accumulate at a level above the oil. In an inclined stratum capped by an impervious rock the oil and gas migrate up to a higher level than the water. The capillary attraction is a force that plays an important rôle in this migration. The cap-

illary attraction of oil is less than that of water; hence it is assumed that water, through capillary attraction, may force oil from rocks having small pores, such as shales into rocks having larger pore space, such as sand stones.

No doubt the compacting of sediments by their own weight is an important factor in compelling movements of included fluid; other causes are increased temperature, as sediments accumulate affecting the fluidity of the oil. A reduction of the pore space in the rock by cementation would compel migration.

The Storage of Oil

The migration of the oil in the rock will affect its segregation in commercial quantities only when the natural storage conditions are suitable. The rocks are capable of holding a gas or liquid in proportion to their porosity, and any rock that is porous may, under favorable conditions, serve as a reservoir. As a rule, sands and sandstones are high in porosity and much of the oil secured is taken from sands or sandstones, but not all sands and sandstones are sufficiently porous to serve as reservoirs, nor is the same horizon as a rule uniformly porous.

Locally, the pore space in the sandstone may be partly or wholly filled with a cementing substance, thus reducing or destroying the pore space and, at the same time, destroying the storage capacity of the rock. Limestone frequently stores large quantities of oil and gas in the pore space incident to shell breccias or in solution cavities. Dolomitic limestones are often notably porous rocks. Shales, which are the source of much oil, have themselves a very limited storage capacity, owing to the fine texture of the rock.

Geologic Structure Favorable to the Accumulation of Petroleum

The migration of oil due to various causes into porous rocks is not of itself sufficient to bring about accumulation of oil in large quantities, except in localities where the structural conditions are favorable. If a rock is uniform in porosity and horizontal in position, it may contain a considerable quantity of oil and gas and not afford favorable conditions for segregation of oil or gas in commercial quantities.

In nature it is rare to find a rock uniform in porosity or entirely horizontal in position, and, as a rule, they vary very much in porosity and departure from the horizontal.

Favorable structural conditions are those which bring about segregation of oil and gas in commercial quantities and such conditions are very varied and difficult to classify. A number of the best known conditions favorable for the accumulation of oil may be described.

An Inclined Porous Stratum

It has already been stated that rock formations rarely, if ever, lie entirely horizontal in the earth and that inclination from the horizontal is a very common condition. The effect of departure from the horizontal in a formation containing oil will be apparent. If the stratum contains both oil and water, the oil will be forced by the water up the dip. In such inclined strata, there is no obvious trap to retain the oil and, if the pressure of the water is sufficient, all the oil will be driven out of the strata at the surface as an oil seep

Reduction of the porosity of the rock near the surface may retard the movement and form a trap to hold the oil at a definite level. In case of an inclined stratum of this kind, when the necessary variation in porosity to form a top is lacking, the oil extruding from the surface for a time may deposit a heavy residue in the pores of the sand upon evaporating to such an extent as to cement the sand and thus form a trap for the retention of the oil.

Folded Strata

Instead of being merely tilted, the rock strata may be folded in such a way as to form a trap to retain the oil. As a general rule the folding is more or less complicated.

Anticlinal Folds

As a rule in nature an upfold is more or less complicated by a downfold called a syncline. The oil and gas moving up on reaching the anticline may be trapped and accumulate until the anticline fold is filled, if there is sufficient oil and gas to fill it.

If the stratum contains water, it will be in the syncline and if no water, the oil will be in the syncline. Folds in rocks may be symmetrical in form or lacking in symmetry. Unsymmetrical are the most common. The folds in a formation may extend in the direction of the dip or across the dip, depending entirely on the conditions bringing about the fold.

Faults

Very frequently, faults bring about conditions favorable for the storage of oil. The movement of certain portions seals the formation along the fault plane, thus creating an oil reservoir.

Domes

In its simplest form an anticline is an upfold or arch in the strata or may be thought of as a bulging up of the strata. Domes may be, but are not necessarily, accompanied by compensating structures known as basins. Domes serve as an ideal trap for oil

and gas as they are closed on all sides. They form a sealed basin in which the oil is retained. A very exceptional type of structure is known as salt domes and they are frequently oil-bearing near the Gulf of Mexico, and the central portions of such domes consist of a mass of salt; in some of the domes the salt core comes nearly to the surface. Overlying the salt is anhydrite and above the anhydrite a mass of sulphur.

The cap rock is generally limestone and, above this, clays, shales and other sedimentary rock. The process by which such domes were formed remains undetermined.

Their importance as oil reservoirs arises from the fact that salt and associated minerals have pushed up the sedimentary rocks resulting in a dome structure favorable for the accumulation of oil and gas.

Volcanic Plugs

Volcanic plugs or intrusions coming up into sedimentary in some instances push up the strata in such a way as to form storage reservoirs for oil.

Depth of Wells

The question often heard is the depth to which it is necessary to drill to obtain oil. The question in all probability is prompted by the supposition that oil can be obtained at any place, provided drilling is continued to sufficient depth, but such is not the case; in some localities oil is obtained at a very shallow depth, while in other parts of the earth it is not reasonable to expect that oil can be obtained at any depth.

In some locations, oil has been found in commercial quantities at a depth of 100 feet or less and, on the other hand, many wells produce oil at from 4,500 to over 5,000 feet. In drilling, the cost increases rapidly with depth, and only wells that are large producers repay the expenses of deep drilling; on the other hand, shallow wells producing a small quantity are profitable.

Surface Indications

Oil in many instances is indicated by oil or gas seeps at the surface. It is not to be assumed that seeps at the surface in all cases indicate oil in commercial quantities below the surface. On the other hand, oil below the surface in all cases does not outcrop at the surface, and many valuable oil pools have been located with no surface indications in the way of oil and gas seeps.

Many of the oil and gas seeps on investigation prove to be something other than oil and gas: Iron oxide scum is very frequently mistaken for an oil scum; when an iron scum is broken it forms

angular fragments which do not readily unite, while, on the other hand, an oil scum breaks in round fragments and readily unites. The oil scum is not readily removed from the hands by washing, while the iron scum is readily removed on washing.

Other gases than petroleum gases are found at times coming from the earth, such as carbon dioxide and hydrogen sulfide.

Most of such gases are non-inflammable and can be recognized by their odor. Inflammable gases coming continuously from a strong flowing spring are likely to be coming from a considerable depth and can be regarded as favorable indication of oil or gas.

Geologic Investigations

The object of geologic investigations should be to determine whatever should be made known in regard to the property in advance of drilling or in addition to drilling, as the case may be. In these investigations the geologist will take into consideration the character of the underlying formations or sediments, whether petroliferous or not, and the probable depth of the producing horizons, if such are believed to exist.

In determining probable structural conditions, evidence as to the position of the strata may be obtained by observations on the surface formations determining the direction and amount of the dip. Surface topography must be used with care in determining underground structures; only occasionally do hills coincide with anticlines.

In examining a property the geologists will take into consideration all structural features that can be determined. The character of a portion of the underground rock can be determined from cullings from wells previously drilled or may be inferred from outcroppings of formations coming to the surface some distance away. Oil and gas seeps would indicate petroliferous formations, but are not the only indications and are by no means always present, even in areas underlaid by oil and gas.

Methods of Drilling

The two common methods in use for drilling wells are the rotary and the percussion drills. Rotary drilling is practicable where the formations to be drilled through are relatively soft but operates at a disadvantage in a hard formation.

The percussion drill is used to advantage where the formation is hard. In the percussion method drilling is by means of a heavy drill, which is alternately lifted and dropped, thus breaking or pounding its way through the rock. The broken or pounded portions of the rock are removed by a bailer, the rock material being suspended in water. For a large cable rig such as is necessary for

deep wells, a derrick is built on the well site by which to support and handle the machinery.

The rotary method is entirely different from that by cable tools. In the rotary drill a string of pipe extends from the top to the bottom of the well, the pipe revolves and cuts into the rock. The loose pieces of rock are floated to the surface by means of a stream of water which is carried into the well through the drill stem and back around, that is, outside the pipe The cable method is generally used when drilling in new territory, due to the fact that the character of the rock is more readily determined when drilling by cable than rotary.

In new territory, to fully determine the character of the formation, the use of the diamond drill is advisable, and by this means a continuous core is taken in the hard rock formation which is of inestimable value in prospecting for oil and gas.

Composition and Properties of Oil and Gas

The petroleum compounds, oil and gas, are natural products found within the earth, composed essentially of hydrogen and carbon. In addition to hydrogen and carbon there may be present in oils a small amount of nitrogen sulphur and oxygen.

The petroleums found in nature, although consisting of two essential elements, are of extremely varied composition and have been shown by chemical analysis to form compounds which may be arranged in several series, and of each series there are many members. The more common petroleum compounds are those which are included in the paraffin, olefine and napthene series.

Less common in nature are compounds of the acetylene and benzene and several other series. The petroleum compounds of the paraffin series, also known as the methane series, consist of hydrogen and carbon combined in certain definite ratios. In the following table is given the name and formula of the common gases and oils of the paraffin series. The first four of these are gases under ordinary conditions.

Name	Gas	Formula
Methane	"	CH_4
Ethane	"	C_2H_6
Propane	"	C_3H_8
Butane	"	C_4H_{10}
Pentane	Oil	C_5H_{12}
Hexane	"	C_6H_{14}
Septane	"	C_7H_{16}
Octane	"	C_8H_{18}
Nonane	"	C_9H_{20}
Decane	"	$C_{10}H_{22}$

In the olefin series there are, in all cases, twice as many hydrogen atoms as there are of carbon atoms. The general formula of the series would therefore be CnH_2n.

Paraffin Base and Asphalt Base

Certain of the petroleum oils, particularly those of the paraffin series, upon evaporation leave a paraffin residue. Other petroleum oils, including those of the olefin and napthene series, upon evaporation leave asphaltic residue.

Accordingly in commerce, petroleums are commonly known under these two main divisions: namely, those having a paraffin base and those having an asphalt base. The asphalt in oils is said to be due to the inclusion of sulfur and oxygen compounds in the oil

The petroleums of a paraffin base are of more value for refining purposes than are those having an asphalt base. Hence, the classification of oils as of paraffin base and asphalt base is of commercial value.

Specific Gravity

The specific gravity affords an important aid in judging the quantity and value of oil for refining purposes, the lighter oils as a rule being more valuable than the heavy oils. Since the oils are lighter than water the actual specific gravity expressed in the ordinary way is less than one.

In ordinary uses a special scale has been devised known as the Baumé scale, in which the gravity is expressed in whole numbers On the Baumé scale, distilled water at 60° F. has a gravity marked as 10°, and the figures on this scale are so arranged that they increase as the gravity of the fluid decreases.

Paraffin base oils are usually light and hence on the Baumé scale have a higher reading than asphalt base oils. The color of crude oil varies from light yellow or straw color to black. As a rule, oils of light color are likewise light in gravity. The odor varies decidedly, depending in all probability on the included gases. Hydrogen sulfide gas is often present in the oils from limestone, giving a disagreeable odor. A tropine odor is often detected in light-colored oils. Aromatic odors and an odor of gasoline characterize some of the crude oils.

Another property in which oils differ much among themselves is viscosity or fluidity.

As a rule the light or paraffin base oils flow readily. Some of the heavy oils are so viscous as to require heating somewhat before they can be pumped through a pipe line.

The Refining of Oil

Crude oil is received at the refineries from the pipe line or from tank cars and is generally stored in 55,000 barrel steel tanks. There is no average size for a refinery, and they vary from 50 barrels per day to thousands of barrels per day. In general, the larger the refinery the more efficient and economical the operation.

When petroleum is heated, it begins to boil at a temperature so low that the heat will not injure the skin. It is not the whole of the petroleum which is boiling, only the lightest part, that is, the gasoline or naphtha. If the temperature is held constant for a short length of time all the gasoline would have boiled off; with the temperature remaining the same the boiling will close.

If the temperature of the oil is raised to some higher figure it again begins to boil, and now it is the kerosene constituent of the crude petroleum which is being converted into vapor and driven out of the liquid. After a short period the kerosene will be gone and as before the liquid will cease to boil.

In this manner the various constituents of the petroleum will be separated one from another.

The apparatus employed for the purpose of separating the oils is called a still, and these stills have been developed to a large capacity, some of them holding 50,000 gallons or more. In such stills the temperature of the crude petroleum is gradually raised and with each elevation in temperature a different product is boiled off until finally nothing remains in the still except a small quantity of black residue known as petroleum coke.

The cooling and condensation of the vapors is accomplished by means of an apparatus called condensers, which is connected to each still. This consists of a coil of pipe submerged in a tank of cold water. The vapor coming from the still is cooled and condensed to a liquid condition in passing through this worm.

The fraction which has the lowest boiling and is, therefore, driven off first is the gasoline, and the character of the condensed liquid delivered by the pipe from the condenser coil to the house will automatically change the connections in the receiving house so that the next distillate will be received in a separate tank. The second distillate which comes into the receiving house and is thus diverted into a separate tank will be the illuminating oil. In the early days of the industry everything was practically waste except kerosene.

The next product driven off after the illuminating oil is a somewhat heavy and discolored free-flowing oil called gas oil. This oil is seldom sold to the retail trade, as its chief use is for the manufacture of city gas. Most refineries make a cut in gas oil, separating it into a high quality and a low quality gas oil.

The next product after the gas oil and the last important product of crude petroleum is the lubricating oil. The paraffin is separated from the remaining oils by chilling the mass in a refrigerator apparatus and there pressing the oil out of the mass.

TANKERS

The close connection between petroleum and maritime commerce was assured from the day the United States was recognized as the chief reservoir of the world's supply. The function of the old whaling ships is now performed by the modern oil tankers.

The modern tanker dates from the launching of the Atlantic on the Tyne in August, 1863. This was the first ship designed to carry oil in bulk. The first ocean-going ship to be fitted with iron tanks for the transport of petroleum and to be equipped with pumps for unloading was the Charles, a Belgian ship. This ship was fitted with iron tanks estimated to carry 7,000 barrels of oil, and this sailing vessel plied between New York and European ports from 1869 to 1872.

The rapid growth of the industry in the eighties proved that the converted oil ship was not economical, and this led shippers to demand an improved tanker bill in such a way that absolute control could be exercised over the oil, a demand which resulted in the construction of tankers free from risk of waste and dangers. In contrast to the Belgian ships' capacity, the larger types of modern oil tankers will carry more than 4,500,000 gallons.

The larger petroleum organizations do not depend on private shipping firms to carry their products, but build their own vessels. A few years ago it required days to load or unload a 10,000 ton ship This task is now completed in a few hours, being handled by use of powerful pumps. Due to the rapidity of loading and unloading oil ships do more sailing than any other class of ships. In transporting crude oil short distances by water, barges are used.

THE TIME OF DAY

By Professor ALFRED H. LLOYD
UNIVERSITY OF MICHIGAN

SECOND PART[1]

VIII

BUT, to forget Bunyan and Christian and perhaps in more senses than one to come really back to earth, our present-day materialistic realism is beginning to appear in a different character from that often if not usually assigned to it. It is only "carrying on" for what was, expanding and liberating the past. The traditions of a long history, already traced here in several ways, are actually discoverable in it. It fulfills, not supplants, the past. True, to face the case at its worst, even consciousness and will are now said to be physical. The soul itself, if any longer one may use the word at all, is said to be physical. Yet, this granted for argument's sake, even for candor's sake, and all that Freud would insist on added just for good measure, the physical world is no longer what it was and much of our time's materialism is merely an amazing anachronism. Our history-ignorant materialists suggest to me a man having an unpleasant name like Gottesliebe or Himmelhoch and actually delighting in its rudeness until one day learning its true meaning. Thus, whatever the physical world was centuries ago,

[1] The first part of this essay appeared in the November number. After urging that it was very important to-day that the time of this twentieth century be told, not by mere boastful dates, however large and nobly round the figures, but by weight of actual conditions and opportunities, the writer represented the century as weighted with at least three important things: (1) Anthropology, the intimate and naturalistic and scientific study of man, including psychology, now so cordially in the company of such sciences as botany and zoology and physiology, and psychiatry, now at least presuming to give most sensuous and realistic, if not materialistic, "close-ups" or exposures of man even to his very soul; (2) technology with its amazing development of standard methods and external automatic machinery, and (3) new and great adventure. The anthropology was shown to be fourth in a sequence of intellectual interests marking great eras of Christendom: theology with the dogmatic institutionalism of the medieval church, mathematics and mechanics in the seventeenth and eighteenth centuries, biology in the nineteenth with its epoch-making evolution-hypothesis, and to-day the intimate and at last wholly unreserved science of man. Furthermore, so recounted, the great story of Christendom from a narrow supernaturalistic institutionalism, holding man quite aloof, to the present broad naturalism was interpreted as indicating on a grand historic scale man's gradual adaptation to the natural environment and as implying mergence, not

astronomy, mathematics, biology and psychology have greatly transfigured it, actually bringing into it or revealing out of it, as we shall see, facts or opportunities once associated only with the spiritual aloofness of the orthodox religion and its church. For, being at once naturalistic and intimately anthropological, science may indeed be giving us that "close-up," even to startling and offensive exposure, but therein, instead of only the surrender of all that is ideally human and humanly treasured to what is natural and unpleasantly physical, there is at least with as much truth a transfiguration of physical nature Poor is the rule, as you know, that does not work both ways Not more has matter taken spirit to itself than spirit matter Who really examines the evidence, for example, translating the German, so to speak, will find that by the very science of it the whole life of sense from being blindly instinctive and close, immediate and uncontrolled, is to-day positively and openly on the whole under more actual constraint than ever before in the whole history of Christendom. Any other conclusion would be only self-deception when not downright dishonesty. Violence is naturally so much more obvious than law and order and so much better as a "story" whether to the writer for the newspapers or to other materialists and sensationalists

Listen! To-day, if someone says the room is cold or hot and another is of different opinion, how is the question settled? By the thermometer, as inconvenient and standardizing to personal feeling and judgment as the church of old A young mother living not far from Ann Arbor, for very excellent cause was once prompted to give her son a vigorous spanking. Did her anger and its quick circulation and nervous condition get the better of her? Not at all. Being modern and objective and "materialistic," being also although only in spirit ecclesiastical, she first took his temperature in

necessarily loss, of all that had been spiritual in the natural or physical. It indicated also, as the ruling idea of a theocratic institution gave way to that of natural mechanism, mechanism to organism and organism finally to the conscious and willing individual of present science, a process describable as expansion of life and "liberation of the spirit." And, lastly, it revealed a moral progress, a pilgrimage, in which Christendom appeared as journeying midst many adventures and hardships, not after Bunyan from this world to the next, but from that other next world so predominant for human interest in the middle ages, to this, now so absorbing and, thanks to the intimacies of anthropology, so sensuously real. Finally, if really meaning such adaptation and expansion and liberation, the day's materialism, its direct and unreserved naturalism, might not be as unspiritual as very commonly supposed. Some assurance was to be got, too, from Bunyan himself and the orthodox sensuous realism of his very account of Heaven and its sensuous glories. Moreover, he saw that "there was a way to Hell even from the Gates of Heaven." Possibly even the feared and to many distressing naturalism of our twentieth century, if faced and understood, in its turn will show a spiritual path.

order to be sure that illness instead of punishable obstinacy were not the source of his obstreperousness. Alas, his temperature proved normal. Curtain! Could a Father Confessor have been more considerate or as deliberate? Ghosts of the medieval church! Hovering over our modern "physical" life! Moreover, besides thermometers we have thermostats, the temperature by institutional authority for much of our life to-day.

Nor is the "stat" principle, which always makes for standardization, by any means confined to our temperature sense. It has been applied and is getting every day more refined as well as more elaborate and more comprehensive in its application to every phase and department of our life, sensuous or rational. Under our modern scientific and anthropological realism—I all but misspoke and said ecclesiastical instead of scientific!—we are indeed and are, as never before, members one of another in a standard life. Even our breakfasts come in uniform packages under trade-names. According to Hugh Walpole, recently lecturing in this country, our very novels to-day are more generic than friendly and human and personal. In a current journal I find—observe carefully this title[2]—"A statistical study of ethics" in which are tabulated certain more or less common practices "in order of worseness," sex irregularity, stealing, cheating, and so on, the mathematically graded list ending in smoking, next to last, and dancing, at least relatively innocent and last.

What, pray, are we coming to? Rather, where have we come? Essential institutionalism and standardization! With such ethics, with thermometers and their sort, with all the modern "stats," with mental tests or personality measurements and ratings, of which we heard so much during the war and have at least not ceased to hear a good deal since, with our new methods of examination and classification, whether for college or for life, so empirical and statistical in method, so definitely standardizing and allocating in results, with these and much else in kind, all of course, as we may infer, for some wonderful mobilization, we shall soon be all labeled as but so many models of certain letters or numbers, Model A or B, Model 13 or 23, and among other consequences our various institutions of education will enter upon an era of standardized quantity production and in due time may make important contribution to the setting up of a hierarchy never yet even distantly approached for efficiency and accomplishment. To biological or physiological eugenics, which would "scientificize" and perhaps Mendelize the family beyond even Plato's dream, we shall have added something

[2] "A statistical study of ethics," by Professor A. P. Brogan, University of Texas, in the *International Journal of Ethics*, January, 1923.

of the same general sort in the regions of mind and spirit. Already I have boldly quoted a future historian. May I now read from a morning paper of some years, never mind how many years hence:

> Yesterday, Commencement Day, was a record-breaker in the life of the college. The orator of the day spoke impressively on "Scientific institutionalism or efficient gradation and quantity production in the things of the spirit," and at conclusion of his most eloquent and stimulating address labels were placed on more graduates in the higher models than ever before. Only in Model 13 was there any falling off. Names and figures follow.

In a word, thanks to science and its realism, which no longer spare the sanctuary of man and his nature and which in spite of our mood for laughter we must take seriously, even "remaining to pray," standardization and quantity production in the human product, as in automobiles, are of the spirit of the time, and it is a safe prediction that, for better or for worse, we are only in the earlier stages of the amazing enterprise. In still another word, too, thanks to science being evidently but the widely liberated spirit of ecclesiasticism, being this spirit opened and deepened for larger and fuller life, "you may break, you may shatter" the medieval régime, "if you will," but the mechanical efficiency, the uniformal constraints and the pyramidal, hierarchical classifications or gradations, as well as the great underlying purpose—alas, long ago I lost the meter, yet not the rhyme!—"will cling to it still."

IX

We are, I think, beginning to understand our modern physical world so-called and the spiritual possibilities of it. This world the day's psychology would have our souls "join" and our souls, having cherished memories, have hesitated. But let me go on Still more can be told. Ours is in truth a life of sense, of seeing and hearing, of instinctive passion and desire; it is, too, such a life under constraints of uniformity and impersonal standards, as the thermometers and the thermostats were showing us; but, more than this, also with benefit of science it is rapidly becoming world-wide in its actual and sensuous reach; it is near to being—what is the great word out of the past?—ecumenical, that is, comprehensive of the inhabited world. I was saying that the big things of life had somehow made the world small. We used to look out of our windows and see the things of our own yards or streets or hillsides or from those windows hear only what our unaided ears might get. Now, with benefit of the same standpoint and methods of science which are dictating to mankind a naturalistic realism, our eyes and our ears may reach, not just in imagination, but sensuously, what

in rest or in motion belongs to regions far away, even around the world The very curvature of the earth no longer obstructs. Moreover, others far away share with us sensuously, realistically; I mean audibly, visibly. Not only in the specific sense, but more generally, not merely literally but figuratively "broadcasting" and its ecumenical realism belong to our day, the great heritage of our generation Very recently I was reading a paper giving report of Edouard Belin's promise of television. Add broadcasting to that! The newspaper, the telephone and the phonograph, color photography and motion photography, the wireless and the radio even as we know these to-day, may soon seem insignificant beside what is coming. Still, apart from all rash prophecy, the present day offers quite enough to indicate clearly what the materialism and the realism of our time may mean Time and space no longer set limits to our senses. With no mere personal glasses or ear-trumpets are we having real experiences beyond our unaided powers, but with an increasingly efficient general and standard instrumentation of life we are, not playing at sensing, but actually sensing the whole world. Let me say even once more, yet with fuller meaning, that we are become in no mere fanciful or sentimental way members one of another. How wonderfully physical, how golden withal and musical, how shiningly real is become the possible life of the human spirit.

Am I forgetting something? Doubtless. But, specifically, psycho-analysis? As well as what according to the librarians are at least among the most soiled books on the shelves? Am I forgetting the primitive—or primary?—instincts of nutrition and reproduction, the passions and desires, that no institutional life or no instrumentation proceeding from science can ever successfully suppress, can ever suppress without disaster to body and mind? Am I forgetting the evidence that these afford for a raw and wholly unspiritual realism and that has apparently been inspiring many recent novels and dramas as well as much else in our art and literature and pretended morality? Not for a single moment. The evidence, as frequently it is taken, is fallacious. Why expect successful suppression? For a word so misleading if not actually treacherous I would substitute instrumentation or mediation, that is, informed and purposed control, as at once more natural and more scriptural. I would also suggest—expecting to be understood—that the mediation or, say, the controlling instrumentation just for morality's sake be enlightened and up-to-date, that is modernly, not medievally, scientifically not just traditionally and legalistically, institutional. Why be behind our times in what is so fundamental to the very life and urge of all times? Or, on the

other hand, why be a raw realist and materialist, soiling life as well as those books, when the very science which has written the books means, if in spirit and methods and results it mean anything, objective and ecumenical standards, in short, social control, not just personal license? Why not see those passions and desires, no longer in the abnormal complexes incident to a too medieval suppression, but in the normal and safely controlling complexes of life to-day as with our wider view and greater understanding, with our natural laws at once more obligatory and more dependable, with our wiser and safer candor,—which we must avoid confusing with deliberate exposure, and with our general broadcasting life is being lived? Why by too much conservatism actually invite disastrous license instead of promote real freedom?

An automobile was wrecked in our street a few days ago I inspected the ruin, talked with the humiliated as well as injured driver, and concluded that, forgetting himself and lapsing consciously he had had a Freudian or at least some very modern dream of driving old Dobbin and a buggy on some country road. If we will but bring our life of sense, instinctive as well as more conscious and intellectual, up to date, treating it as by no means immediate and loosely free but mediate and controlled with world-wide contacts, we need take no alarm for morality from our time's realism, scientific and ecumenical. At least morality and hygiene, whatever may transpire for politics and economics, may have benefit of the big things that have been making the world small and compact. Even hunger and sex are now in world mediating and controlling complexes.

Once more I am in my one-time host's dining-room, and in the color of the walls at last I do see the intriguing primary coat. Intimately, in the scientific and naturalistic anthropology and psychology of to-day or in the materialistic realism, which they dictate, and which gets its sensuous and physical reality through the broadcasted experiences of the inhabited world, I feel, and would have others feel, subtly but really, spiritually not literally, the great past of Christendom as this from its beginning has been expanded and refined in those successive stages of theology, mechanics, biology and finally anthropology.

How hard it is to-day to get away from the telephone! Or to do without it! In a now relatively small way the ordinary telephone may remind us how far and how concretely our selves reach to-day. Talking to Europe by wireless is getting to be an old story. A good deal of water has gone under the bridge since the prophetic William James, always given to picturesque ways of expressing great principles, told us how the soul of a fop might be in

and act from the top or possibly the gloss of his beaver hat or the swinging and knocking of his nobby cane. The flapper, I suppose, by the same token might act from the center or base of her flying and rattling galoshes. To-day the self, when serious and alert, when consciously and actively and responsibly its own real contemporary, is confined to the reach, not of some girl's expansive footwear or some foppish man's tall hat or swinging cane, but of controlled electricity.

X

Technology, including artifacture—instead of manufacture—to the point of a highly developed automatic machinery was, as will be recalled, the second of the specially selected signs of our time of day Discussion of this may be brief, since what has already been said of the first, anthropology and psychology, of their physical scientific "close-up" of man, and of the whole world by the remarkable control of electricity brought sensuously close to a coincidently expanded individual, can not but help greatly to the understanding of the second, technology. Anthropology and technology are indeed closely related. They are to each other very much as an organism to its habitat or, better, as conscious humanity to the more or less external instruments by which human life is provided with a free medium.

Thus it has become clear to us that in a real sense we are to-day conscious, that we experience what we do experience, not immediately and with unaided senses or faculties generally, but very often and very normally for our time mediately and even vicariously. Either we ourselves are really expanded in the way suggested already or—as only another and significant way of getting at the same truth—our experience is nowadays in large measure had or conducted for us. Not only is much of our seeing and hearing as well as much even of our thinking—remember, for simple example, the computing machines in our business offices and the newspapers, alas more often partisan than accurate—done for us, but also, to come to the matter of our present interest, in this age of technology the very labor of life, effecting this, producing that, is being taken off our human shoulders. In other words, ours is an age of almost self-running and strangely intelligent machinery. A well-nigh objective or external, automatic, vicarious artifacture is rapidly supplanting direct and humanly taxing and costly labor and manufacture In war, too, as in peace, mere direct man-power is meaning less every day, while a more productive or more destructive power has been taking its place. One's little finger touching a button or a lever and to do so needing an intelligence only commensurate with it may start machinery that will effect in a short time

results which not long ago in our history required hundreds of men, working for days and weeks with long hours and wearing and wasting hardships and in the end producing what in quality and quantity was not as serviceable or efficient. Yes, our era of anthropology with its world-broad realism is also coincidently and consistently an era of technology and a world-supplying productivity. Our mediated and vicarious consciousness and our mediated and vicarious labor simply belong together.

About two centuries ago there was an interesting Frenchman[3] who ventured to write of the possibility of an animated statue. How seriously he wished to be taken it is hard to say. But to-day, far outrunning his speculation, we have had fabricated for us and already engaged in doing much of our work a wonderfully intelligent automaton. The Iron Man,[4] he is being called by some, or the Great Automaton, the Vicarious Army or the Modern Giant. He is, of course, no mere dumbwaiter or curate's assistant or Lazy Susan. He is, all in one, an unnumbered host of such useful creatures and a great deal more and his service is not just here and there personal or domestic but generally social and even syndicated. "Intelligent," I called him. It is, in fact, he who sees and thinks for us in all those ways of our vicarious consciousness from the thermometer to the wireless as well as works for us. Children of the future will suffer no lack of stories about a wonderful giant; a cruel giant perhaps; perhaps, properly approached, a very friendly one.

I may not and need not tell the story of his gradual fabrication or—as better to say—of his growing up to his present maturity and power. It would be only the story of Christendom in one more way, quite parallel to what has been told here already. Yet this I will say. It is but the story of a low efficiency through direct and always costly exploitation and mobilization of human creatures in an army or rigid institutional personnel or mechanically organized group or gang of any sort giving way to the mechanically far more productive and humanly far less costly efficiency through aid of the Modern Giant. In it all, too, nothing can have more interest than the striking fact that only as man has clearly found himself in the natural world, abandoning his one-time aloofness and submitting himself to the observations and close exposures of natural science, has he gained the ready service of the Giant Automaton and, whatever be in store for the future, had his already notable immunity from the direct exploitation of earlier times. Otherwise put, it would seem to be no mere accident that at the same time the human person has become an object of intimate science and the

[3] Buffon, 1707–88.

[4] See "The Iron Man of Industry," by Arthur C. Pound, Boston, 1922.

Giant Automaton has been fabricated and set to work May it be that the liberation through the latter has really removed the hardship and loss that some have fancied in the former? Those to whom science and its materialism have meant only the complete undoing of man, making him mere creature of matter, should pause to observe and reflect. Behold the Giant Automaton, truly an irrefutable witness to what they would think, the very creature of matter which they imagine—except, of course, for his size and power By his size and power he is no "mere creature" But reflect that he is not man after all. In fact by him from what he is, automatism and all, man himself is freed! Accordingly, save among those who insist on looking at one thing but seeing another, his real testimony just by virtue of his vicarious instrumentation of life is that matter and machinery are for man, not man merely for or of them.

In any case the term, physical, really is appearing to be like those guttural names, Gotteshebe and Himmelhoch, only harsh in sound; when understood, by no means so in meaning The day's materialistic and naturalistic realism is actually inaugurating a new era for the human spirit Alive, as we have found it, with the nobly purposed but now broadened and deepened and so greatly spiritualized traditions of the past, bringing man and nature intimately close but at the same time either expanding man to a world-reach or so contracting the world as to make it all near and real to man, and freeing man through automatic machinery set to his service from exploitation, it ought possibly to go under another name. For a fact, did Spirit ever have the door of idealistic opportunity more widely opened?

XI

There was to be considered, finally, a third sign of our time: anthropology, technology, adventure; the third, adventure, like all true adventure, bringing no mere expansion of what has been, no mere accumulation in kind, but a different quality of life and a new valuation, say a new humanism.

Perhaps from what has been said the reader has already felt adventure as present or as soon coming. Possibly his own experience of life to-day has been as of a charged atmosphere suggesting adventure not without danger. Still, to appreciate the adventure, the possible new opportunity now opened to mankind, do but consider, to begin with, how general the recent actual or at least now wholly possible benefit of life is, some of course enjoying much, others having only some of the new leisure, and then reflect how very different must be the quality of the new life thus made possible. In some degree a leisured democracy instead of just a

leisured class is promised. Thanks to machinery, everybody may expect more time off, "shorter hours"; but, aside from such liberation and leisure, there may be expected a certain leisure in active life, not just from it, as we get more used to the efficiency, to the automatism and to what some call our present speed The old instrumentation of life, directly dependent on man-power and in its movement fatiguing and exhausting for man when not also destroying, has inspired, even among those who were personally involved in it, poetry, art, philosophy, human reflection and appreciation generally, but to-day the new vicarious instrumentation of life is only just beginning to be taken in a spirit sufficiently leisurely for such reflection and the intimate human expression always proceeding from reflection. In some degree, however, a leisured democracy already belongs to the day's adventure; in some degree our day's active life is also getting more leisurely and reflective; and, life itself being so different, a new valuation of life, accordingly, with all that this implies, may be or must be near at hand

Riding in an automobile, whether as driver or as passenger, is certainly experience of a different quality from riding behind animals that can grow weary or from being carried, with literal meaning now or in metaphor, by one's own fellow-beings whose fatigue and subordination one can not help feeling. In general, too, leisure or leisureliness through automatic machinery and standard impersonal and objective systems must be very different in its quality from leisure, necessarily much more limited to the few, by direct human service. The Giant Automaton can not grow weary; at the same time his efficiency is very great; and with the new freedom which he brings a new valuation, as was said, a new and deeper humanism, would seem inevitable.[5]

Accordingly, while not disposed to hail novelty loudly or recklessly, while recognizing the danger of seeming to advocate or preach it, I can still understand sympathetically the day's groping for novelty in art, literature, morals, religion, in all the humanities, in economics also and in politics, as only so much natural adventuring to meet the day's demand for new values. So much of life has become automatic We have bottled and tinned and canned not merely our foods but in subtle and sensitive machinery our labor and to a startling extent our very culture, our music, our drama. These are all provided for us vicariously. Small wonder that our human spirit between hope and fear, real freedom and a license as dangerous as at times it has seemed even unbalanced, is reacting aggressively to the challenge, bent on adventures in humanism.

[5] In an essay, Ages of Leisure, one of several essays recently published under the general title of Leadership and Progress (Boston, 1922), I have discussed this subject at greater length.

Consider, furthermore, how remarkably and how quietly science has wrought. Small wonder the atmosphere seems charged. We are to-day, probably without clearly realizing it, members or subjects of a régime, most deftly elaborated by science in all the varied ways of its interest and activity. The dynamic possibilities of this no one of us can measure Our widespread industrialism, as we hear it called, has cared relatively little for the laws of state, a great deal for those of physical nature. Is there now any important industry without its laboratories, its experiment stations, its support of scientific research, its high-salaried scientific workers? Such devotion to science, then, and to its applications, not indeed confined to industry but conspicuous there, has effected a remarkable régime, a great organization, and of course organization always means mobilization of the latest available forces and resources. To-day, moreover, the mobilization already effected or now promised can hardly be overstated. In history from as many years before Christ as you please down through the centuries we read of invading hosts. In our very recent times we often have had counted for us the vast population of one region of the earth or another and have been warned in conclusion against this colored peril or that and its irresistible numerical power. It may be that history-making must still go on in that way. The spots of the leopard may be quite unchangeable. But the power in the régime already inaugurated by science is at least no power by mere populations and enjoyment of its benefits may not depend on mere physical man-power or numbers. As part of our day's adventure, then, is the chance of supplanting the old power with the new and of so developing the new as to set the nations or the races, whatever their populations and available fighters, on a basis of equality with respect to the old and so secure against its attacks.

Political scientists might say of science's régime with the new power which it is mobilizing and the worldwide reach of its various instruments that it is at present rather *de facto* than *de jure*; that is, quite actual but still unofficial. So it is and its full inauguration and development only wait on official recognition. It needs, in other words, to be idealized and to be made purposive and church as well as state is now being asked to recognize it. Will the state respond? Will the state recognize the world-domain of the new régime, the world-reach of the new power, the ecumenical realism of the life of to-day? Not in so far as any state, like our own, continues to feel or at least to cry "Isolation!" when *de facto* there is no isolation. Will the church give its sanction? Not in so far as any church, Presbyterian or Episcopalian or what you will, continues to betray its Christian origin by still asserting some narrow orthodoxy or fundamentalism or a mo-

narchical and supernatural theism, when the expansiveness of God has long left such things behind? For a time the two, both state and church, by their inertia may defy the new régime and its broad and essential theocracy, but the fact remains that man and nature have been brought sensuously and realistically close, the world has been made intimate and small, and man depends too much on memory not still to insist on spiritual values and new opportunities. The small-town statesmanship or churchmanship of some of our so-called contemporaries, who would still think of the conduct of the world and its affairs as if no one's view could extend beyond the top of the first mountain range or more than three miles out to sea or beyond the letter of a fourth century creed and who by their more obstinate than honest conservatism are inviting disastrous violence rather than real and constructive progress, may well remind us of that man whose car was wrecked because, forgetting that old Dobbin was not still in the shafts, he neglected the necessary long view of the road The *de facto* régime must be consciously recognized, idealized and made *de jure.*

XII

I know well that this which I have been calling the régime, the *de facto* régime, set up by science, has often been in disfavor among others besides the conservative theologians and politicians. So many have seen only the dead machinery and the materialism of it and have no sense of the wealth of meaning and ideal value in it. In book after book, in essay after essay, great alarm has been expressed over the wide and blighting rule of machinery.[6] Some have even proposed that we give it all up, call science and its gift of the new power a failure or a disaster, and ere it be too late get back once more to the simple horse-and-buggy life of the good old times. And why not? Or why stop even there? I can reply only that those remonstrants seeming to prefer for a slogan "Back to nature!" instead of "On with nature!" ought to read their Bibles, if they can find them. Scripturally as well as morally and in broad sense biologically it is proper to use for possible return the talents one has, not to neglect them. We are told that modern machinery is killing individuality, destroying the fine qualities of personal interest and initiative, whereas, as I have to believe, it is making possible such adventures in individuality or personality as the world has not yet known. Remember how we have found most intimately associated with the growth of the Great Automaton a noteworthy distribution of leisure or in work itself the possibility of a new and reflective leisureliness. Remember how out of these may come, as was suggested, a new humanism with new depths of inner

[6] See, for example, "Social Decay and Degeneration," by R. A. Freeman, Boston, 1921.

life and new reaches of character as well as new outlook and understanding. Our age of machinery, then, ought to challenge the humanities, not discourage them, and develop personality, not kill it. Some there are now, as ever before, who refuse to hear opportunity when it knocks at the door or who take alarm, hearing the knocking, lest they may have to leave their comfortable firesides. Which would they? Have history move forward in spite of their home comfort and inertia or with their active interest and bold co-operation?

But automobiles, they persist, are making the legs of men atrophied; adding-machines are weakening the mind; and, in general, from lack of necessary exercise physical or mental man is getting flabby. Degeneration is already setting in. Moreover, let body and mind go and the soul will follow. *Mens sana in sano corpore.* To which must be added: *Spiritus integer in integri mente.* All quite true and also showing imperfect if not already degenerate thinking. So might one argue from every gain or advance in life. Making the old effort no longer necessary, it is bound to bring laziness and eventual degeneracy! But whence came that old effort? Can we not trust the source of that for new effort now? And under conditions that hold still larger possibilities of gain? Is there not a fable somewhere of a creature who, having been well-fed and at first feeling only the satiation of his meal, exclaimed as he stretched himself for sleep: "Now is all done. I need strive no more" Later, however, and my memory do not fail me, the food assimilated, he was out on the hunt with more strength and more alertness and a wider field than ever before.

XIII

May I now be humored a little? Allow me to court fancy. It is poor thinking, after all, that does not sometimes lapse in this way. East and West! Personality and Power! Only yesterday I was reading with much interest an article[7] by a Chinaman, who had been studying at Columbia University. This was his subject: "Why China has no science." The West has had science; the East not. Why? Character and happiness, says the writer, Yu-lan-Fung, have been the passion of China, of the East generally; power over nature has been the passion of the West. "Westward the course of empire takes its way" is a line of early eighteenth century versification often quoted at least by Americans before the present century. Now, I suppose, the East is getting too near, alarmingly near. Is any distance left between it and the western frontier?

[7] In the *International Journal of Ethics*, 1922, V, xxxii, pp. 237–263.

Personality and power! To-day we are beginning to see that as pursued by East and West these have been only qualified successes, like most half-truths. Is it that each has subordinated and neglected the concern of the other, seeing this only darkly and, as it were, during the night and so irresponsibly? Is it that, figuratively as well as literally, East and West have exchanged day and night, responsibility and irresponsibility? Again and again we hear that in temporal things the East has been very corrupt, according to one report "making the politics and economics of New York or Chicago look like a Sunday School," while in spiritual and intimately personal things the West either has been goody-goody and pharisaical or has cultivated defensive complexes of irresponsibility and environmental determinism.

Allow me, then, to imagine that at this time of Christendom's history, when important adventures in personality are among the adventures now offered, the Eastern question, whether peril or opportunity, may easily prove more than just the economic and political question which in general it has appeared. In India and China, in the East at large, the Western question in its turn is prominent if not dominant. But, to speak as one moving west, technology by its power over nature has at last made the world small, overcoming the curvature; the intimacies of anthropology have made man primarily man and world-wide, only secondarily racial or ethnic and local; and the two may end by making East and West, West and East, each with its half-truth, meet the other at least half-way. In other words, once more in history the West may turn to the East for spiritual help. Prophecy and folly look as alike as twins; but there is, to say the least, ground for expecting from the future, not only still undreamed-of powers over nature, but also new depths of character and personal individuality. More character in the West might, perchance, be the best maneuver against the alarms and perils of the colored East.

XIV

For the day, finally, so charged with adventure is this life of ours, all things seem in a great flux. In extraordinary measure nothing that was, state or church, industry or morals, art or science, seems any longer what it was. Reactions settle none of the problems. Mere violence only stimulates and perhaps justifies reaction. Is this? Is that? Is anything any longer? Anything stable and dependable? Familiar feelings these and often spoken questions, reflecting the groping spirit of every department of life. A number of troubled souls, simply exhibiting in religion what is the situation everywhere, got together not long ago somewhere in the maelstrom of New York and after much futile communing

finally sent out to a score of scientists and philosophers over the country a questionnaire with this for their first query: Do you acknowledge the existence of God? And for their second: If you have just answered yes, has your answer been from faith or reason? There could hardly be, at least in these days, more irrelevant and more futile questions than those two. Such questionnaires, by no means confined to matters of religion, are born of a sort of mental and moral inertness, when bold action is what is needed. Nothing ever just exists in a critical time, in a time of transition. To-day, to have what one would one must not just look for it in some pigeon-hole or get one's friends together and make them search their pockets or, these devices failing, in desperation send out a lot of yes-or-no questions and so let a vote settle it all. The city fathers of San Francisco once voted that there was no plague in the city! One must, in a critical time, will what one would. Will, not a passive faith nor yet a formal reason, is the primary faculty of adventure. So, I say, merely believe in nothing to-day; also take nothing just from reason; will everything that past experience and present opportunity seem to make worth while. Faith may recall and cherish and suggest; reason is ever an excellent guide, a finder of ways and means; but will ventures and realizes.

And, while there can be obstinacy and inertia, sometimes taken for will, while there can be impulse and its fascinating blindness, taken not infrequently for virtue, there can not be good will or true will, there can be no effective and progressive activity, there can be no virtue where there is no clear sense of the time.

Spirit of the Renaissance! Of the eastward crusades and the westward explorations! Once more bold and pious adventures in naturalism and in humanism, in power and in character! Progressive purpose spiritualized with cherished memory! Man's will awakened and again bent on having what it would! In such phrases I would sum up our time of day and its challenge. But every one should keep in mind that the world to be awakened to-day is the world of to-day as anthropology and technology have been making it, and making it real, not that of five centuries or more ago as the medieval régime had instituted it. Should be remembered, too, that to-day's adventures in naturalism and humanism are still, like Christian's of those earlier days, such as can attain nothing worth while without possible disaster always attending. Reality is still, as then, like gold.

"Then I saw that there was a way to Hell, even from the Gates of Heaven."

THE PSYCHOLOGICAL BASIS OF DEMOCRACY

By Dr. THOMAS R. GARTH
UNIVERSITY OF DENVER

If one desires to work with a material substance of any sort, he does not hark back to alchemy for his method of procedure, but he quickly brings to his aid that most painstaking science called chemistry or that of physics. If one seeks to solve a problem of mind scientifically, he calls for no ghost of the past or present. He does not play around the door of that charlatan, the "sub-conscious," nor does he seek anything bizarre, but just science. He recognizes that science is really what it claims to be and may not sit in the corner with mysticism and superstition and still be science. He realizes that there is a sisterhood of the sciences and that they work in harmony; that psychology must not be regarded as the ghost that walks in the laboratory of natural science but must be actually a part of our great scientific system.

This being so, then society may come to psychology for assistance in the solution of her problems. In this case let us take the problem of the Psychological Basis of Democracy. When one remembers what James had to say of the evanescence of the "will" as the expectant seeker approaches the psychological cupboard, he is seized with fears that he will find it bare or only meagerly supplied. Upon looking into the inventory he discovers nothing labelled "Democracy." He only finds a set of reflexes, instinctive behavior, tendencies, pure and derived, learned acts spun out of these, preparatory reactions, consciousness in forms of sensation, memory, imagination, recognition, physical and mental trial-and-error, etc. Almost sick at heart he may start to turn away, until he remembers that human life is a synthesis of all these and that, moreover, this is our inventory of all scientific psychology; and if the psychological basis of democracy is to be found anywhere, it is to be found just here.

He makes now a more critical examination of the problem, perhaps, and notes that the term democracy is a term of social import. It indicates the activity of many human beings. But this helps little, for the psychology of the group is the psychology of the individual mind as found in groups under certain conditions. We must seek that form of behavior of the individual that occurs in a democratic situation.

The question now is: How does the individual behave in a situation called "democratic" that would differ from one that is not "democratic"—a non-social situation if such will be singled out just here? We perhaps may safely say that all democratic situations are problem situations. This inference leads the way to the solution of the very problem we are trying to solve. For we quickly ask ourselves, "By what method can the individual solve his problem?" Dynamic psychology is prompt to answer, "By the trial-and-error method." Trial-and-error is a term to conjure with in educational and psychological circles, but the method has a history that goes beyond the time when it was first singled out by Professor Edward L. Thorndike as the one by which an animal learns. Folk sayings couched the method in various vulgar forms of expression such as: "If at first you don't succeed, try, try again," getting a thing done by "hook or crook," "going at it by main strength and awkwardness." As intimated, it came into respectability from its humble folk origin through the door of the laboratory of the animal psychologist. Then later was noted the trial-and-error character of the learning of chicks to drink and to pick up their food (Morgan), of cats and chickens to escape from cages of imprisonment to food on the outside by means of learning to raise latches and pull strings (Thorndike), of earthworms to withdraw from the irritating stimulation of light rays (Yerkes), and of white rats to open cages and run mazes (Watson). In fact, the method stood out so prominently in the animal laboratory that human psychologists soon took the cue and by means of laboratory studies on human beings announced their conviction that human learning was fashioned after the same method, *i.e.*, trial-and-error. Human subjects were observed in their method of learning the solution of common mechanical puzzles (Ruger), learning to send and receive telegraphic messages (Bryan and Harter), to do typewriting by the touch method (Book), to toss balls (Swift), to run mazes blindfolded (Hicks and Carr). Studies have been made as well of learning a foreign language. What is more, reasoning as well as learning is now said to be merely trial and error with mental elements. Such materials as geometric problems and common folk riddles have been used to demonstrate facts to support this last generalization.

In its ideal and scientifically theoretical form the method may be thus pictured, no feature of which may be omitted: (1) A situation practically new to the learner; (2) a drive within the learner which makes urgent the solving of the problem presented by the situation; (3) features in the situation calling out such native or learned responses as the learner may possess; (4) success and failure in successive trials to meet the situation; (5) elimination of the

failures and persistence of the successes; (6) satisfaction produced by the successful response favoring its fixation in the nervous mechanism, that is, the successful responses become more and more firmly established because of frequency and facilitating tendencies, while on the other hand the wrong responses die out from sheer lack of innervation and from inhibitory tendencies; (7) the learner meeting the situation with speed and accuracy raised to highest indices of efficiency. This is the picture of the method of trial and error, this is the picture of the method of human and animal learning. Can it be the picture of human social as well as individual progress? Before we undertake answering this question, let us present the method working in some erratic form in the individual.

In the first place, the situation must be thought of as new or one to which the individual is not adapted. If the organism is alive, some response will be called forth whether the situation is old or new. If it is old, adaptation is made immediately and satisfaction sets in. But if new, the innate tendency to bring about the end-response persists until some means is found for satisfying the tendency with that satisfying end-response. Then an erratic situation might be (1) one in which the drive would be absent. There can be no trial and error without a drive, *i.e.*, no learning without a tendency. So the individual may fail to learn because of absence of a drive. Again (2) the situation may be all that is desired, likewise the drive may be present, but the responses may be thwarted in one way or another so that their effect on the situation is not felt. Or (3) it may be that all the energy is being absorbed by some wrong though habitual responses, so that some more modest but perhaps more promising one never has an opportunity to make its trial. The fact is this is just the thing that is likely to happen in an experienced being: habits are more vigorous than new forms of behavior and tend to crowd them out. The learner should keep a very careful watch on these old forms of behavior for fear they will throttle the more promising new unestablished forms. (4) On the whole an erratic situation may arise by any factor preventing by intention or accident the free trial and error of the organism in its effort to meet the situation.

In all the above we have meant to bring out the fact that the essential elements of the method of trial and error are: (1) An aroused drive and (2) a free and varied response to features of the situation.

Coming nearer to an answer to our question raised above as to whether social progress comes about by trial and error of a social sort, we may say that we do not ordinarily take the view (but we may safely do so) that the individual organism is a society, as it were—it has its hands and feet, its eyes and ears, its reflexes and

learned processes, its instincts and experiences, and when a situation arises which must be met or the organism must perish, it requires a very free participation of all the factors of the whole man to meet the situation. The eye may not say to the ear in such time of stress, "I have no need of thee;" nor may the hand say to the feet, "I have no need of thee." It may be possible that some modest, insignificant, long-past experience may be just the thing needed for the solution of the problem in hand. In fact, it would be foolhardy for the organism to allow the "tying up" of the hand so that it might not participate in the free trial-and-error process, for it might be just the instrument needed. And even though so much of the organic colony remain inactive because of the fact that it is not needed for overt action, still, though inactive, there must be a sympathetic coordination of all of it. There is a sort of participation by the apparently inactive parts. The right hand always knows what the left is doing by sympathy. We will call this *coordinated trial-and-error of the individual organism,* and it is free and whole-hearted as long as all members are earnestly participating. This is the method of democracy of the individual organism.

In order to answer the question as to the psychological nature of the method of democracy, we ask the further question, By what magic has the psychology of the individual changed when we regard him as a unit in a social group? To be sure, his learning of responses looking to social adaptation is characterized by trial and error. Social progress means the adaptation of the individuals of the group to their natural environment and to each other. The question is still a problem of the individual organism in learning how to meet a situation, though he is a unit in a group, a link in a chain. "No chain is stronger than its weakest link"; a group is strong or weak as its units are strong or weak. A social group is never really static. Always playing on the individuals composing it are the features of a present situation, and this situation is new, one to which the group is not adapted, even though its features arise within itself as individuals influencing one another. The individual drives come into play. Here is action and interaction as the social trial and error proceeds. And the learning is genuine for the individual and the group as the individuals participate freely in it. Tendencies aroused in the individual seek their end-responses and persist until they do really find them. Satisfactory adjustment of the group means satisfactory adjustment of the individuals composing the group, and the trial and error continues as this point is approximately attained. New situations arouse dormant tendencies which function for further learning or progress. As the method of learning for the individual is free, unhampered trial and error, of

the individual's repertoire of native and acquired reactions upon the situation, so is the method of democracy the free, unhampered trial and error of its individuals acting in groups.

Old social forms of adaptation fall away with changed situations, and as new tendencies begin to function a reformation sets in because of a renaissance. A renaissance arises because of the discovery of old manuscripts. A medieval mind awakens from darkness of superstition by the shifting from the tendency of fear to that of enjoyment of life. A social revolution occurs when the tyranny of rulers is apparent to those being ruled. Industrial hands and feet become restless when they suspect injustice on the part of the overlord. Orthodoxies, sufficient unto the day, until a new slant is gotten on God and the universe, crumble away when the individual minds begin to question.

Social learning or progress is hampered as long as (1) the situation remains unchanged, whether natural or social, (2) the individuals fail to feel the drive, (3) the individuals do not freely respond because of indifference or compulsion to inaction. Cocksureness is represented by activity on the part of isolated members of the group who deliberately prevent the free action of others, however humble, which, of course, is contrary to the principles of learning, and also makes impossible coordination of all parts. Restricted activity, whether it be caused by an absolute monarch or a benevolent despot, is still a case of limited response of the individual and so of hindered development of the individual and consequently of the group.

Well-meant clerical officiousness is no exception and might well hang a millstone about its neck rather than delimit the intelligent trial and error of its individual parishioners.

The case seems clear. The ideal of democracy is free trial and error, since the procedures are one and the same method. For the case of social activity, we have trial and error in which all the individuals of the group participate. If some members of the group are prevented from participating by being compulsorily isolated, the group suffers, and so likewise if some members are inactive because of indifference. It makes no difference as to the cause of the inactivity. If some members of the group should undertake to solve all or a few of the problems in the absence of some of the members, they may be guilty of cocksureness, which has hindered the solving of many a problem of the single individual.

To summarize, this, then, is the psychological basis, the psychological method of democracy; *i.e.*, absolutely free trial and error of the members of the group all sincerely looking to the solution of some social problem. Social trial and error may be hindered

in one way only, in which case it actually ceases to be the trial-and-error method, and that is when only one part of the group undertakes to handle the situation and the remaining part is inactive. In individual psychology—and it is just as true in social psychology as we understand it—the latter situation may arise in two ways: Indifference involving the inactive part and enforced inactivity likewise involving that part—both of which prevent the free trial and error of all parts, and there is no trial-and-error process after all if it be not of a whole-hearted nature *Cocksureness* is an illustration of restricted activity. It is a case of one's gratuitously assuming that he knows how to meet the situation, when in fact he has little right to make such an assumption. It is a mark of a low intelligence in the individual whenever this attitude characterizes all one's voluntary acts, and one is intelligent to that degree in which he becomes "as a little child," as it were, getting down on the humble level of trial and error when the situation demands it.

Finally, it may be well to ask if there are any really democratic situations of this free trial-and-error sort where all members actually are engaged in the solution of some social problem. It would be an ideal situation if there were. But we have no real democracy as a purely psychological process in this sense. The effort will be ever to strive to approach it and always to stimulate all members to earnest and intelligent participation in the free trial-and-error activity for the solution of social problems.

SOME BEARINGS OF ZOOLOGY ON HUMAN WELFARE[1]

By Professor J. H. ASHWORTH

THE bearings of zoology on human welfare—as illustrated by the relation of insects, protozoa and helminthes to the spread or causation of disease in man—have become increasingly evident in these later years and are familiar to every student of zoology or of medicine. At the time of our last meeting in Liverpool, insects were suspected of acting as transmitters of certain pathogenic organisms to man, but these cases were few and in no single instance had the life-cycle of the organism been worked out and the mode of its transmission from insect to man ascertained The late Sir Patrick Manson, working in Amoy, had shown (1878) that the larvae of *Filaria bancrofti* undergo growth and metamorphosis in mosquitoes, but the mode of transference of the metamorphosed larvae was not determined until 1900. Nearly two years after our last meeting here the part played by the mosquito as host and transmittor of the parasite of malaria was made known by Ross. In addition to these two cases at least eight important examples can now be cited of arthropods proved to act as carriers of pathogenic organisms to man—*e. g.* Stegomyia—yellow fever, Phlebotomus—sandfly fever, tsetse-flies—sleeping sickness, Conorhinus—South American trypanosomiasis (Chagas' Disease), Chrysops—*Filaria* (*Loa*) *loa*, the flea *Xenopsylla cheopis*—plague, the body-louse—trench fever, relapsing fever and typhus, and the tick Ornithodorus—African relapsing fever. In selecting examples for brief consideration I propose to deal very shortly with malaria, although it is the most important of the insect-carried diseases, because the essential relations between the Anopheles mosquito and the parasite are known to every one here. There still remain lacunae in our knowledge of the malarial organisms. Ross and Thomson (1910), working in this city, showed that asexual forms of the parasite tend to persist in small numbers between relapses, and suggested that infection is maintained by these asexual stages. Such explanation elucidates those cases in which relapses occur after short intervals, but the recurrence of the attacks of fever after long intervals can only be explained by assuming that the parasites lie dormant in the body—and we know neither in what part of the body nor in what stage or

[1] From the address of the president of the Section of Zoology of the British Association for the Advancement of Science. Liverpool, 1923.

condition they persist. Nevertheless, the cardinal points about the organism are established, and preventive measures and methods of attack based on a knowledge of the habits and bionomics of Anopheles have been fruitful in beneficial results in many parts of the world

If we desire an illustration of the vast difference to human well-being between knowing and not knowing how a disease-germ is transmitted to man, we may turn to the case of yellow fever. When this pestilence came from the unknown, and no one knew how to check it, its appearance in a community gave rise to extreme despair and in many cases was the signal for wholesale migration of those inhabitants who could leave the place. But with the discovery that Stegomyia was the transmitting agent all this was changed. The municipality or district took steps to organize its preventive defences against a now tangible enemy, and the successful issue of these efforts, with the consequent great saving of life and reduction of human suffering in the Southern United States, in Panama, in Havana and in other places, is common knowledge. It is a striking fact that during 1922 Central America, the West Indies, and all but one country of South America were free from yellow fever, which has ravaged these regions for nearly two centuries. The campaign against Stegomyia is resulting, as a recent Rockefeller report points out, in yellow fever being restricted to rapidly diminishing, isolated areas, and this disease seems to be one which by persistent effort can be brought completely under control.

In 1895 Bruce went to Zululand to investigate the tsetse-fly disease which had made large tracts of Africa uninhabitable for stock, and near the end of the same year he issued his preliminary report in which he showed that the disease was not caused by some poison elaborated by the fly—as had been formerly believed—but was due to a minute flagellate organism, a trypanosome, conveyed from affected to healthy animals by a tsetse-fly (*Glossina morsitans*). In 1901 Forde noticed an active organism in the blood of an Englishman in Gambia suffering from irregularly intermittent fever, and Dutton (1902) recognized it as a trypanosome, which he named *Trypanosoma gambiense*. In 1902 Castellani found trypanosomes in the blood and cerebro-spinal fluid of natives with sleeping sickness in Uganda, and suggested that the trypanosome was the causal organism of the disease. The Sleeping Sickness Commission (Bruce and his colleagues) confirmed this view, and showed that a tsetse-fly, *Glossina palpalis*, was the transmitter. Since then much has been learned regarding the multiplication of the trypanosome in the fly and its transference to man. For some years this was believed to take place by the direct method, but in 1908 Kleine demon-

strated "cyclical" transmission, and this was shown later to be the principal means of transference of *T. gambiense*. In 1910 Stephens and Fantham described from an Englishman, who had become infected in Rhodesia, a trypanosome which, from its morphological characters and greater virulence, they regarded as a new species, *T. rhodesiense*, and its "cyclical" transmission by *Glossina morsitans* was proved by Kinghorn and Yorke. Recent reports by Duke and Swynnerton (1923) of investigations in Tanganyika Territory suggest that direct rather than cyclical transmission by a new species of Glossina is there mainly responsible for the spread of a trypanosome of the *rhodesiense* type. The impossibility of distinguishing by their morphology what are considered to be different species of trypanosomes, and the difficulty of attacking the fly, are handicaps to progress in the campaign against sleeping sickness, which presents some of the most subtle problems in present day entomology and protozoology Here also we come upon perplexing conditions due apparently to the different virulence of separate strains of the same species of trypanosome and the varying tolerance of individual hosts—on which subjects much further work is required.

The relation of fleas to plague provides one of the best and most recent illustrations of the necessity for careful work on the systematics and on the structure and bionomics of insects concerned in carrying pathogenic organisms. Plague was introduced into Bombay in autumn 1896, and during the next two years extended over the greater part of Bombay Presidency and was carried to distant provinces. The Indian Government requested that a Commission should be sent out to investigate the conditions. This Commission, which visited India in 1898–99, came to the conclusion (1901) that rats spread plague and that infection of man took place through the skin, but—and this is amazing to us at the present day—"that suctorial insects do not come under consideration in connection with the spread of plague." Further observations, however, soon showed this conclusion to be erroneous. Liston found in Bombay in 1903 that the common rat-flea was *Pulex (Xenopsylla) cheopis*, that it was present in houses in which rats had died of plague and in which some of the residents had become infected, that the plague-bacillus could multiply in the stomach of this flea, and that the flea would—in the absence of its usual host—attack man. These observations pointed to the importance of this flea in the dissemination of plague, and the Second Plague Commission, which was appointed and began work in 1905, definitely proved that *Xenopsylla cheopis* is the transmitter of the plague-organism from rat to rat and from rat to man. The mechanism of transmission of the plague-bacillus

was worked out by Bacot and Martin in 1913. They showed that in a proportion of these fleas fed on the blood of septicaemic mice the plague-bacilli multiply in the proventriculus—which is provided with chitinous processes that act as a valve to prevent regurgitation of the blood from the stomach—and a mass of bacilli is formed which blocks the proventriculus and may extend forward into the esophagus. Fleas in this condition are not prevented from sucking blood because the pharynx is the suctorial organ, but their attempts to obtain blood result only in distending the esophagus. The blood drawn into the esophagus is repeatedly forced backwards into contact with the mass of plague-bacilli and on the sucking action ceasing some of this infected blood is expelled into the wound. The transmission of plague depends on the peculiar structure of the proventriculus of the flea and on the extent to which, in certain examples, the plague-bacilli multiply in the proventriculus. Such "blocked" fleas being unable to take blood into the stomach are in a starved condition, and make repeated attempts to feed, and hence are particularly dangerous.

Until 1913 it was believed that all the fleas of the genus Xenopsylla found on rats in India belonged to one species—*cheopis*, but in that year L F. Hirst reported that the rat-flea of Colombo was *X. astia*, which had been taken off rats in Rangoon, and described by N C. Rothschild in 1911. Hirst ascertained that this flea did not readily bite man if the temperature were above 80°F. A collection of 788 fleas from Madras City proved to consist entirely of *X. astia*, and Hirst suggested that the explanation of the immunity of Madras and Colombo from plague was the relative inefficiency of *X. astia* as a transmitter. Cragg's examination (1921, 1923) of 23,657 fleas obtained from rats in all parts of India shows that they include three species of Xenopsylla—namely, *cheopis*, *astia*, and *brasiliensis*. This last species is common in the central and northern uplands of peninsular India, but its bionomics have not yet been investigated. *Cheopis* is the predominant species in the plague areas, while *astia* is the common flea in those areas which have remained free from plague or have suffered only lightly. In Madras City, for instance, during the twenty-one years, 1897–1917, plague has occurred in twenty of these years, but the average mortality was only .013 per thousand—that is, though the infection has been repeatedly introduced there, it failed each time to set up an epidemic. The significance of an imported case of plague depends in large measure on the local species of Xenopsylla. Hirst has made numerous attempts during the plague season in Colombo to transmit plague by means of *X. astia* from rat to rat, but with negative results, and *X. astia* was never found to behave like a "blocked" *cheopis*.

The distinction of *X. cheopis* from *X. astia* is not an entomological refinement with purely systematic significance, but corresponds with a different relation of the species to the epidemiology of plague, and hence becomes a factor of great practical importance. If through these researches it has become possible by examination of the rat-fleas of a locality to estimate accurately its liability to plague, anti-plague measures may henceforward be restricted to those areas in which plague is likely to occur, *i.e.*, where *cheopis* is the predominant flea. Thus, a great economy of effort and of expenditure and a higher degree of efficiency may be achieved; in fact, the problem of the prevention or reduction of plague may be brought from unwieldy to practicable proportions When it is remembered that since we last met in Liverpool some ten and a quarter millions of people have died in India from plague we have a more than sufficient index of the importance of a precise knowledge of the systematics, structure and bionomics of the insect-carrier of *Bacillus pestis.*

Another of the outstanding features of the period under review has been the extensive and intensive study of the Protozoa. The structure and the bionomics and life-history of these organisms have been investigated with the help of the finest developments of modern technique. It is fitting here to record our acknowledgment to two staining methods—Heidenhain's iron-haematoxylin and the Romanowsky stain (including Giemsa's and Leishman's modifications), which have added greatly to our technical resources.

There is time to refer only to certain of the Protozoa which directly affect man. Twenty years ago our knowledge of the few species of Protozoa recorded from the human alimentary canal was defective in two important respects—the systematic characters and the biology of the species—so there was much confusion. Subsequent investigations, and especially those of the last ten years (by Wenyon, Dobell and others), have cleared up most of the doubtful points, but owing to the difficulties of size and the paucity of characters available it is by no means easy in practise to distinguish certain of the species. Of the seventeen species now known to occur in the intestine of man *Entamoeba histolytica* has received particular attention. This organism lives as a tissue parasite in the wall of the large intestine, where, as a rule, the damage caused is counterbalanced by the host's regenerative processes. But when the destruction outstrips the regeneration intestinal disturbance results, leading to the condition known as amoebic dysentery. The specific characters and the processes of reproduction and encystment of *E. histolytica* are now well ascertained, and it is realized that in the majority of cases the host is healthy, acting as a "car-

rier'' dangerous to himself, for he may develop into a case of acute dysentery, and to the community—for he is passing in his feces the encysted stage which is capable of infecting other persons. Whether an infected person will suffer from dysentery or act as a healthy ''carrier'' apparently depends upon his own susceptibility rather than on any difference in the virulence of different strains of the Entamoeba.

In all work with human Entamoebae there is need for critical determination of the species, for, in addition to *E. histolytica*, a closely similar species, *E. coli*, is a common inhabitant of the intestine. This, however, is a harmless commensal, feeding on bacteria and fragments derived from the host's food. The distinction between the two species rests chiefly upon the characters of the nuclei and of the mature cyst—quadrinucleate in *histolytica* and octonucleate in *coli*—and considerable care and technical skill are requisite in many cases before a diagnosis can be given. And yet this distinction is definitely necessary in practice, for indiscriminate treatment of persons with Entamoeba is indefensible; treatment is only for those with *histolytica*; it is useless for those with *coli*, and subjects them needlessly to an unpleasant experience.

A notable result of recent work is the proof that the more common intestinal Protozoa, formerly believed to be restricted to warmer countries, occur indigenously in Britain. This was first established by a group of observers in this city, and has been confirmed and extended by subsequent workers. There is good reason for believing that in this country the incidence of infection with *E. histolytica* is about 7 to 10 per cent., and with *E. coli* about five times as great (Dobell).

The discovery (1903) of Leishmania, the organism of kala azar and of oriental sore, added another to the list of important human pathogenic Protozoa, but the mode of transmission of this flagellate has not yet been proved.

Of the problems presented by the parasitic worms the most momentous are those associated with Ancylostoma and its near relative Necator, which are prevalent in countries lying between 36°N. and 30°S.—a zone which contains more than half the population of the earth. Heavy infection with Ancylostoma or with Necator produces severe anaemia, and reduces the host's physical and mental efficiency to a serious degree. Until 1898 there was no suggestion that infection was acquired in any other way than by the mouth, but in that year Looss published his first communication on the entry of the larvae of Ancylostoma through the skin, and in 1903 gave an account of further experiments which proved that dermal infection resulted in the presence of worms in the intestine.

At the meeting of this association in Cambridge in 1904 Looss demonstrated to a small company his microscopical preparations showing the path of migration of the larvae. His investigations served to establish the importance of the skin as the chief portal of entry of Ancylostoma, and pointed the way to effective methods of prevention against infection.

Another notable advance in helminthology is the working out of the life-cycle of Schistosoma (Bilharzia)—a genus of trematode worms causing much suffering in Egypt and elsewhere in Africa, as well as in Japan and other parts of the world. These worms when mature live in pairs, a male and female, in the veins of the lower part of the abdomen, especially in the wall of the bladder and of the rectum. The eggs, laid in large numbers by the female worm, provoke inflammatory changes, and cause rupture of the veins of the organs invaded. Until about ten years ago the life-history of Schistosoma had been traced only as far as the hatching of the ciliated larva or miracidium which takes place shortly after the egg reaches water, but it was then shown that this larva is not, as had been held by Looss, the stage which infects man. Miyairi and Suzuki (1913) found that the miracidium of *Schistosoma japonicum* entered a fresh-water snail which acted as the intermediate host, and Leiper and Atkinson (1915) confirmed and extended this observation, and showed that the miracidia develop into sporocysts in which cercariae are formed. We owe chiefly to Leiper's work (1915–1916) our knowledge of the life-history and method of entry into man of the Egyptian species of Schistosoma. He demonstrated that two species of this parasite occur in Egypt, and established that the miracidia develop in different intermediate hosts: those of *S. mansoni* enter Planorbis, while those of *S. haematobium* penetrate into Bullinus—the molluscs being abundant in the irrigation canals. The sporocysts produce cercariae, which escape from the snails and gather near the surface of the water, and experiments with young mice and rats showed that the cercariae attach themselves to the skin, enter and reach the portal system from which they travel to the veins of the lower part of the abdomen. Infection of man takes place chiefly through the skin when bathing or washing in water containing the cercariae, though infection may also occur through drinking such water. And so, at last, these worms which have troubled Egypt for at least thirty centuries have become known in all their stages, and measures for preventing infection—which were of great use during the war—have been devised, and curative treatment introduced.

Other recent helminthological researches deserve consideration did time permit, for there has been much excellent work on the life-history of the liver-flukes and lung-flukes of man, and the life-cycle

of the tape-worm, *Dibothriocephalus latus*, was worked out in 1916–1917. Mention should also be made of Stewart's investigations (1916–19) on the life-history of the large round-worm *Ascaris lumbricoides*, during which he made the important discovery that the larvae on hatching in the intestine penetrate into the wall and are carried in the blood to the liver, and thence through the heart to the lungs, where they escape from the blood-vessels, causing injury to the lungs. The larvae, now about ten times their original size, migrate by way of the trachea and pharynx to the intestine, where they grow to maturity. During last year Dr and Mrs. Connal have worked out the life-history of *Filaria* (*Loa*) *loa* in two species of the Tabanid fly, Chrysops, and investigations on other Filarias have thrown light on their structure, but there is still need for further researches on the conditions governing the remarkable periodicity exhibited by the larvae of some species (*e.g.*, *F. bancrofti;* in some parts of the world the larvae of this species are, however, non-periodic). The period under review has obviously been one of great activity in research on helminthes, and fertile in measures tending to reduce the risks of infection.

Insects, protozoa and helminthes not only inflict direct injury on man; they also diminish his material welfare by impairing the health or causing the death of his horses, cattle and sheep, by destroying food crops during growth and, in the case of insects, by devouring the harvested grain. The measure of control which man can gain over insects, ticks and endoparasitic organisms will determine largely the extent to which he can use and develop the natural resources of the rich tropical and sub-tropical zone of the earth.

Other applications of zoology to human well-being can not be dealt with owing to lack of time, but mention should be made of two—the researches on sea-fisheries problems which have formed an important branch of the zoological work of this country for forty years, and the studies on genetics which made possible an explanation of the mode of inheritance of a peculiar blood-group, and of some of the defects (*e.g.*, color-blindness and haemophilia) and malformations which appear in the human race.

The rapid expansion of zoology has brought in its train the difficulty of maintaining the connection between its different branches. There is not only the mental divergence of the different workers, due to the necessity for specialized reading, thinking and technique, but also in some cases spatial separation, and this seems to me to be the factor of greater importance. When modern developments of the subject necessitate expansion of the staff and of the working facilities it has not infrequently happened that one of the newer branches of the subject has been placed in another building, and unless careful arrangements are devised the dissociation tends to

become more marked, so that, to take Mr. Bateson's example, the geneticist becomes separated from his colleague whose interests are more largely in systematic zoology, to their mutual disadvantage.

The actively growing physiological branch of zoology will, it is to be hoped, remain an integral part of our subject; for while there are close and friendly relations between the Department of Zoology and the Department of Physiology, the latter is mainly concerned with the training of medical students, and the teaching and research are consequently, in most universities, chiefly directed to the physiology of mammals and of the frog. The medical physiologist can not be expected to prosecute researches on the invertebrates—these are as a rule too far removed from the matters with which he is especially concerned—and yet many of the invertebrates have been found to be especially favorable for the investigation of fundamental problems which the morphologist with physiological leanings and training seems most fitted to undertake. It is a good sign that more students of zoology are including a course of physiology in their curriculum for the science degree, thus preparing themselves for work in comparative morphology and comparative physiology.

The association of zoology with physiology, and with botany through common problems in genetics and in general physiology, is becoming more intimate. The association of zoology with medicine has become of such importance, especially in regard to its parasitological and its physiological aspects, that clearly collaboration with our medical colleagues in teaching and in research should be as close as possible.

Much has been written and said in recent years about the place of zoology in the medical curriculum, and the present seems a favorable opportunity to reconsider the position and to ascertain the general opinion of the body of zoologists on this important matter. There can, I think, be no doubt that the value of zoology taught in its modern significance is being increasingly appreciated by the majority of our medical colleagues. The minority consists of two categories—those who have not taken the trouble to inform themselves of the subjects nowadays brought to the notice of medical students in the course of zoology, and who apparently consider that this is the one subject in the curriculum in which there has been no evolution since they were themselves first-year students thirty or forty years ago, and those who feel that the increasing pressure in the curriculum calls for curtailment of the teaching in what they believe to be the less important subjects. The first of these categories need not detain us, for an opinion based on obsolete data is valueless. Those in the second category merit serious consideration, but I believe even many of these would change their views if

they knew more fully what is being done in the modern course of zoology to give the medical student a broad, scientific outlook. Even if the course on zoology were cut out the time would not be wholly gained for other work, because many of the subjects now dealt with in the course would require consideration in the teaching of anatomy and physiology. The attention of the medical student is nowadays directed in his course of zoology not so much to the study of details of "types" as to the principles which certain chosen animals serve to illustrate. A reasonable knowledge of structure is obviously requisite before the working together of the parts can be understood, and before general principles can be profitably discussed. The student at that early stage of his education must have concrete examples to enable him to grasp the functions of organs, development, ideas as to the relationships of animals, heredity, evolution, and so on, and his work in the laboratory should give him the opportunity of observing for himself the important structural points on which the principles are based. The practical work can not be limited to what the student can do for himself, for at this stage of his training there are many things which he ought to see but which are beyond his technical powers to prepare for himself, so that a good series of demonstration objects is necessary, care being taken that the student not only sees the specimens but appreciates their significance. As the time given to zoology is limited, the examples for study and the principles to be illustrated are to be carefully chosen, for the course in zoology is not only a discipline but should give basal knowledge of value in the subsequent years of study; and, moreover, if the student can see that his zoological work bears on his later studies he will take much more interest in it. It is important, therefore, that the points of contact of his present with his future work should be successively indicated

The details of the course of zoology for the first-year medical student will vary in the hands of different teachers, and it is well that they should be to some extent elastic. In a minimum course will be included the consideration of two or three protozoa, a coelenterate, an annelid, an arthropod—and especially the features in which it presents advance as compared with the annelid, an elasmobranch fish, and a frog, the primitive features of the fish being emphasized, and the chief systems of organs of both vertebrates compared with each other and with those of a mammal. The functions of the principal organs of all these examples will be dealt with so far as they can be understood from the account of structure—this latter being sufficient to illustrate the principles involved, care being taken not to over-elaborate structural details. Man's place in nature should be considered either in the course of zoology or in

that of anatomy. Other opportunities occur during the course in anatomy, and still more in physiology, for reference to the conditions in lower animals, and if more use could be made of these opportunities the linkage between zoology and the second-year subjects would become much more perfect, and would help in doing away with the watertight compartments into which the average student considers his early medical education to be divided.

The course in zoology should be planned so as to give the student a wide outlook on structure and function, adaptation and environment, some knowledge of the germ-cells and their maturation, of fertilization, growth, regulation, regeneration, decline and death, and an introduction to evolution, heredity and genetics—in general, it should aim at affording a broad conception of the activities and modifications of the organism as a living thing, and should educate the student to manipulate, to observe and record, and to exercise his judgment in matters of inference and of theory.

While some reference may be made in the first-year course to insects and parasitic organisms to indicate the relationship between zoology and pathology and public health, it has seemed to me for some years that the real instruction in entomology and parasitology should be given in the later part of the third or early in the fourth year along with the course in bacteriology. The first-year student, although keenly interested in the direct applications of zoology to medicine, is not competent at that early stage of his career to obtain full advantage from studies on parasites. In most universities a certain amount of time is already set aside in the third year for the study of protozoa, and of helminthes and their eggs, and I have suggested to some of my colleagues in Edinburgh that the teaching on these subjects in the first and in the third year should be brought together in the latter year and remodelled to form a short course of lectures, demonstrations and practical work to cover the essentials required for general practise in this country. By this time the student is much better fitted to appreciate the bearings of this work. I am also inclined to the opinion that a short course of six or eight lectures—on which attendance might be voluntary—on heredity and genetics would be of value in the fourth year to the good student who has a little time at his disposal.

I should be glad if my colleagues would give the section the benefit of their views on the first-year course of zoology for medical students, and on the provision of a course on entomology and parasitology about the third year of medical study.

POPULATION AND UNEMPLOYMENT[1]

By SIR WILLIAM H. BEVERIDGE

In 1876 the birth-rate in this country reached the maximum. At the same time, or just before, important steps were taken for the improvement of public health; the death-rate, which had changed little for thirty years, began to fall, and fell steadily thereafter. There followed a quarter of a century later, as a wave follows a distant earthquake, an abnormal growth in the supply of adult labor. As has been pointed out by Mr. Yule, the number of males aged twenty to fifty-five rose 19 per cent. from 1891 to 1901, as compared with a rise of 14 per cent. from 1881 to 1891, and 10 per cent. in earlier decades. If we take five-year averages the rate of natural increase (difference of birth-and death-rates) reached its highest points in the years 1876–1880 and 1881–1885. Normally, this would have shown itself first by large numbers of boys entering the labor market in the early nineties. At the same time, however, the Education Acts were withdrawing more and more boys under fourteen into the schools. The State dammed up the rising flow of juvenile labor for a year or two. The main pressure in the labor market began to be felt later, *i.e.*, about 1900, and presented itself as the "problem of boy labor," which was really the problem of those who had got boys' work easily enough between fourteen and twenty (replacing the younger children kept at school), but found themselves in difficulties when they reached man's estate. This abnormal movement was bound, for the time at least, to disturb the balance between the growth of capital needed to employ labor and the growth of labor seeking employment. Some temporary pressure in the labor market was inevitable. It might cause a check in economic progress as measured per head of the total population; it would certainly, in the bargaining between labor and capital for the division of their joint product, make labor for the moment relatively weak and capital for the moment relatively strong because scarce. Wages would lose relatively to profits.

All these special influences favor capital against labor. It is in accord with them that, of all our economic indices, that which shows worst, the only one that shows no progress at all from 1900 to 1910, is real wages, the reward to labor; that which almost alone shows continued progress at the full Victorian rate is exports, to be explained perhaps in large measure as the surplus profits of capital.

[1] From the address of the president of the Section of Economic Science and Statistics of the British Association for the Advancement of Science. Liverpool, 1923.

With these points in mind, we reach an economic interpretation of the Edwardian age, reasonable in itself and consistent with other than economic records. That age does not live in our memories and will not live in drama and fiction as a season of hard living and hard labor. It comes back to us now rather in the guise of the ball before Waterloo, as an episode of unexampled spending and luxury; as the time when we saw our roads beset by motors, our countryside by golfers, our football grounds by hundred thousand crowds and a new industry of book-makers, our ballrooms and dining-rooms by every form of extravagance. The smooth development of Victorian days was broken, but the characteristic of the time was rather inequality of fortune than general misfortune; discontent rather than poverty; a gain by capital in relation to labor, by profits in relation to wages, by some classes of workmen at the expense of others, even more than a check to our progress as a nation. Some check to our national progress there probably was, but we are not bound to believe that the check was permanent. The three factors described above—the earthquake wave of labor supply, the South African War, and the upward turn of prices—are all peculiar to their time. The relative shortage of capital would tend to produce its own corrective. Difficulty in absorbing an abnormal flood of new labor does not prove permanent over-population; if all the hundred million persons who now find room and growing opportunities in the United States had landed there at once they would all have starved.

In the last three years before the war we find in nearly all indices resumption of a rapid upward movement. What would have happened if the war had not come? Would the Edwardian age have proved a passing episode of unrest or the beginning of a serious threat to our prosperity? This is one of many questions whose answer is buried in the common grave of war.

In the third place, even if the new century was to see in Britain a lasting and not a transient harshening of conditions, if the rich ease of the Victorian age had gone forever with Victoria, there is little ground for surprise. Malthus or no Malthus, it was not reasonable to expect Britain to keep up forever the speed that marked her start in the industrial race. Providence had not concentrated in these islands the coal and iron supplies of all the world. As the United States and Germany and France developed their own mineral resources, Britain was destined to find her general industrial supremacy challenged, now in one field now in another; she would be driven to discover and maintain those branches of work in which she had the greatest economic advantage, and to withdraw from the rest. This process of challenge and adjustment was bound to occur

irrespective of the growth of population, and as it occurred to give rise to strains and pressures; when accomplished it might yet leave room for progress, if not at the full Victorian pace.

Of Britain before the war we may conclude that the position called for serious thought, not tears or panic. The economic records are open to diverse readings. The check to material progress in the Edwardian age may in part have been less than appears, and in part real but due to transient causes. At worst our industrial rank was challenged, not destroyed; forgetting some of the slacknesses of our easy days, we might through science and system and industrial peace have won a new lease of rapid progress. In this direction lay our remedy; in this, I think, rather than in hastening the process of birth restriction which had begun a generation before.

Let us pass to Britain after the war. Here, statistical tests of progress must be abandoned altogether. War's disturbance of our economic life and all its standards and records is barely subsiding; to found judgments of the future on the course of production or wages or prices in the years of demobilization is vanity. Judgment by recorded results is impossible; we are driven back to general considerations for an estimate of prospects in this new but not better world.

The first principle of population to-day is that under conditions of economic specialization and international trade the population problem in any particular country can not profitably be considered without reference to other countries. The problem in every country is a problem of the distribution of the population of the world as a whole. The actual density in different regions of the earth varies fantastically, according to the part which that region plays in the life of the world, from less than one person per square kilometer in Canada or three in the Argentine, through 186 in Britain, or 245 in Belgium, to 760 in Monaco or 3,538 in Gibraltar. The "optimum density" for any one country at each moment depends not solely or even mainly upon its own resources of natural fertility or mineral treasure, on its own achievements of technique or cooperation, but on how in each of these matters it compares with other countries, on whether other countries are prospering or depressed, on the relations of its own people—in respect of peace or war, of trade or tariffs—towards other peoples.

Britain illustrates this principle more clearly than any other great country, because of all great countries Britain has grown to be the least self-sufficient, the most highly specialized, the most dependent on trade and peace and worldwide cooperation. A pregnant analogy will make the position clear.

In Central Europe, before the war, lived, under one dynastic ruler, a congeries of communities known collectively as the Austro-

Hungarian Empire. These communities formed together a single economic unit, a free-trade area with fifty million inhabitants, in which every stage of economic activity, from the simplest agriculture to the most developed finance, was strongly represented, in which all the separate functions came to be distributed locally according to economic advantage without regard to internal boundaries. Some regions—east and south—were predominantly agricultural; in the northwest were extractive industries of coal and iron, and manufactures founded upon them; further south were other manufactures, and the main seat of commerce and finance. Here was timber; there water-power. Each industry tended to settle where it could most profitably be carried on. Within each industry local specialization often went very far; thus, in cotton, one region predominated in the first and final processes (spinning and bleaching), another had more than its share of intermediate processes (such as weaving); the locomotives for railways came to be built in one region and the wagons in another. In the center lay Vienna, a natural meeting-point entrenched by art in a system of radiating railways, concentrating on itself the most advanced stages of social life—fine manufactures, commerce, distribution, transport, finance, administration—a large and prosperous head directing and nourished by a large body. While the Austro-Hungarian Empire lasted, this headship brought with it the first place in prosperity. The wealth, pleasure and extravagance, no less than the government, education, science and art, of fifty millions made Vienna their center.

The war came and went, and with it went the Empire. The dynastic ruler disappeared; the congeries dissolved; each community became a separate body desiring and needing a separate head, aiming at self-sufficiency, seeking it by economic barriers against intercourse. In that break-up the average prosperity of all the fifty millions has sunk. Nearly every region is in some way poorer than before. But no region has suffered as much as Vienna; in none does the loss take the characteristic appearance of overpopulation. Vienna remains a head grotesquely too large for the shrunken body of German Austria, manifestly overpopulated, as little able to support its former numbers at their former standard as would be Monaco if the nations gave up gambling or Gibraltar if they gave up war. It is overpopulated, not through exhaustion of its natural resources, not because in the past its people were too prolific, but because the world outside has changed too suddenly.

De nobis fabula—the fate of German Austria is the moral for Britain. No other country of comparable size is so highly specialized as Britain. None produces so small a proportion of the food that it requires, or of the raw materials of its industries. None is

so predominantly engaged in the advanced ranges of economic activity; in industry rather than agriculture; in finishing processes rather than the extraction of raw material; in transport, commerce and finance, rather than manufacture. No other country, therefore, is so completely dependent upon the restoration of peace and trade and economic cooperation. None is destined to suffer so acutely from any general disorder. At this moment perhaps none is suffering so much.

It is needless to seek in excessive fecundity an explanation of our present troubles. There are other reasons, enough and to spare, why we should expect now to suffer from unexampled unemployment. Two exceptional causes of unemployment are now added to the normal movement of cyclical fluctuation. One is the difficulty of passing from war and war industries to peace—the difficulty of making swordsmen into ploughboys. The process of training and directing the new supplies of labor to fit the changing needs of industry has been broken by the war; there is a maladjustment of quality between labor supply and labor demand. The second cause lies in the damage done by the war and its aftermath to the economic structure of the world; the destruction of capital, the relapse of great nations towards barbarism, the breaking of easy and friendly intercourse, the continuance of war measures, the smaller volume of international trade and its shifting into new channels. The world has changed suddenly, if less completely, round us as round German Austria. Many of our trades find their former customers dead or impoverished or cut off by new barriers; the labor trained to those trades can not shift to fill the gap in production which is left by the disappearance of those customers and their work. In both these ways, in terms which I used in writing of unemployment fifteen years ago, we have leading instances of those "changes of industrial structure" which leave legacies of enduring unemployment, to be reduced only as the labor ill-fitted for new needs is slowly and individually absorbed again or is removed by death or emigration.

The fate of Austria has a bearing not on war alone. The world may change otherwise than by war. The "optimum density" of population for any country may be diminished not by anything happening in that country, but by the discovery and exploitation of resources in other countries; possibly even by tariff changes. The more any country is specialized in its economic functions, above all if it is specialized in the most developed rather than in the primary functions, the greater is its liability to such changes. Britain, becoming yearly less self-sufficient, setting each year a swiftly growing people to more and more specialized labor, increasing each year its inward and outward trade, was before the war taking more and

more the Austrian risk. It is arguable that with this lesson before us we ought no longer to take the risk so fully; should retrace our specialization and aim at self-sufficiency—in practical terms, under a system of tariffs or bounties, should grow more corn and do less trade. The practical answer to that argument is that we are already too far from self-sufficiency to make worth while any attempt to return. Any change great enough to diminish seriously our dependence on overseas trade, in other words our exposure to the Austrian risk, would involve an impracticable reduction in our total population and our average wealth. A middle course that is sometimes suggested is to aim at self-sufficiency in the British Empire, by tariff arrangements favoring imperial rather than foreign trade. The adoption of such arrangements clearly depends more on the wishes of the Dominions than on those of Britain, and their value for the purpose in view upon the readiness of the Dominions to acquiesce in a division of economic functions which would leave the most advanced and most profitable ones to the British Isles. It is more than doubtful whether this is the Dominion view of imperial economics. In the last analysis, the long road which Britain has travelled to dependence on international trade, as general and as free as possible, will, I believe, be found to be irretraceable. Like the hero of one of Mr. Wells's novels, the Britain that we know, the Britain of forty millions, has been made for a peaceful and co-operative world; she must try to create such a world if she does not find it ready to hand.

Let me try to gather together the threads of this long discussion. A further quotation from Mr. Keynes's writings will serve for a starting-point:

"The most interesting question in the world," he writes, "(of those at least of which time will bring us an answer) is whether, after a short interval of recovery, material progress will be resumed, or whether, on the other hand, the magnificent episode of the nineteenth century is over. In attempting to answer this question it is important not to exaggerate the direct effects of the late war. If the permanent underlying influences are favorable, the effects of the war will be no more lasting than were those of the wars of Napoleon. But if even before the war the underlying influences were becoming less favorable, then the effects of the war may have been decisive in settling the date of the transition from progress to retrogression."

The warning deserves attention. Yet, as I am less inclined than Mr. Keynes to be pessimistic about the tendencies before the war, I feel perhaps more pessimistic than he is in this passage about the effects of the war, and the possibly enduring damage it may have done and be destined to do to humanity. Another criticism that

may fairly be made upon this passage and the paper from which it comes is that in neither is it clear how large an area is referred to, whether Britain or Europe or the world.

Before the war, as I have tried to show, there is nothing to suggest that Europe had reached its economic climax; Malthus's Devil, unchained again or not, can not be found where Mr. Keynes professes to find him. For the world of white men as a whole there is even less ground for pessimism; the limits of agricultural expansion are indefinitely far. If we regard only that part of this world which is known as Britain, judgment is not so easy. Some change did come over our economic life, or certain parts of it, with the turn of the century; our effortless supremacy was challenged. Reasonable men may dispute, and since the decisive evidence has perished will probably dispute forever, whether the unrest and uncertainty of the Edwardian age marked a passing episode destined but for the war to give place to a fresh stage of swiftly rising prosperity, or, on the other hand, recorded the first shock of permanent forces working to make life in these islands less easy and to set a term to material progress.

After the war—for that phase, if indeed we have reached it, I doubt whether we may find much comfort in Napoleonic parallels. The Napoleonic wars were wars between governments and armies rather than peoples; they did not bite deeply into economic life; they left it possible for the best contemporary fiction to show a picture of English society in which the military figure chiefly as dancing partners. The war of 1914–1918 was waged on millions of noncombatants, as much as on armies; it is being continued in the same form to-day; the economic structure of the world, battered out of shape by four years of open war, is still twisted by human passions. The lesson of compulsory self-sufficiency has been learned too well; in all parts of the world, by new economic barriers, nations are endeavoring to safeguard, at the expense of their native and natural industries, the industries which were forced on them by the extremities of war. The world is poorer in resources by its lost years and ruined capital; of those diminished resources it makes worse use.

To sum up, for Europe and its races the underlying influences in economics were probably still favorable when the war began. But the war damage was great and we are not in sight of its end. Man for his present troubles has to accuse neither the niggardliness of nature nor his own instinct of reproduction, but other instincts as primitive and, in excess, as fatal to Utopian dreams. He has to find the remedy elsewhere than in birth control.

Let me add one word of warning before I finish. Examination of economic tendencies before the war yields no ground for alarm as to the immediate future of mankind, no justification for Mal-

thusian panic. This negative conclusion does not discredit the fundamental principle of Malthus, reinforced as it can be by the teachings of modern science. The idea that mankind, while reducing indefinitely the risks to human life, can, without disaster, continue to exercise to the full a power of reproduction adapted to the perils of savage or prehuman days, can control death by art and leave births to nature, is biologically absurd. The rapid cumulative increase following on any practical application of this idea would within measurable time make civilization impossible in this or any other planet.

In fact, this idea is no more a fundamental part of human thought than is the doctrine of *laissez-faire* in economics, which has been its contemporary, alike in dominance and in decay. Sociology and history show that man has hardly ever acted on this idea; at nearly all stages of his development he has, directly or indirectly, limited the number of his descendants. Vital statistics show that European races, after a phase of headlong increase, are returning to restriction. The revolutionary fall of fertility among these races within the past fifty years, while it has some mysterious features, is due in the main to practises as deliberate as infanticide. The questions now facing us are how far the fall will go; whether it will bring about a stationary white population after or long before the white man's world is full, how the varying incidence of restriction among different social classes or creeds will affect the stock; how far the unequal adoption of birth control by different races will leave one race at the mercy of another's growing numbers, or drive it to armaments and perpetual aggression in self-defense.

To answer these questions is beyond my scope, as it is beside my purpose to pass judgment on the practises from which they spring. The purpose of my paper is rather to give reasons for suspending judgment till we know more. The authority of economic science can not be invoked for the intensification of these practises as a measure for to-day. Increased birth control is not required by anything in the condition of Europe before the war, and is irrelevant to our present troubles. But behind these troubles the problem of numbers waits—the last inexorable riddle for mankind. To multiply the people and not increase the joy is the most dismal end that can be set for human striving. If we desire another end than that, we should not burk discussion of the means. However the matter be judged, there is full time for inquiry, before fecundity destroys us, but inquiry and frank discussion there must be. Two inquiries in particular it seems well to suggest at once.

The first is an investigation into the potential agricultural resources of the world. There has been more than one elaborate examination of coal supplies; we have estimates of the total stock

of coal down to various depths in Britain and Germany, in America, China and elsewhere; we can form some impression of how long at given rates of consumption each of those stocks will last; we know that "exhaustion" is not an issue for this generation or many generations to come. There has been no corresponding study of agricultural resources; there is not material even for a guess at what proportion of the vast regions—in Canada, Siberia, South America, Africa, Australia—now used for no productive purpose could be made productive; at what proportion of all the "productive" but ill-cultivated land could with varying degrees of trouble be fitted for corn and pasture. Without some estimate on such points, discussion of the problem of world population is mere groping in the dark. The inquiry itself is one that by an adequate combination of experts in geographic and economic science—not by a commission gathering opinions or an office gathering statistical returns—it should not be difficult to make.

The second is an investigation into the physical, psychological and social effects of this restriction of fertility which has now become a leading feature of the problem. This also is a matter neither for one person—for its scope covers several sciences—nor for a commission; facts rather than opinions or prejudices are required.

If the question be asked, not what inquiries should be made but what action should now be taken, it is difficult to go beyond the trite generalities of reconstruction, of peace and trade abroad, of efficiency and education at home. The more completely we can restore the economic system under which our people grew, the sooner shall we absorb them again in productive labor. Unless we can make the world again a vast cooperative commonwealth of trade, we shall not find it spacious enough or rich enough to demand from these islands the special services by which alone they can sustain their teeming population. Even if the world becomes again large enough to hold us, we shall not keep our place in it with the ease of Victorian days; we dare no longer allow, on either side of the wage bargain, methods which waste machinery or brains or labor. Finally, if there be any question of numbers, if there be any risk that our people may grow too many, the last folly that we can afford is to lower their quality and go back in measures of health or education. Recoil from standards once reached is the gesture of a community touched by decay.

THE IDENTITY OF INHIBITION WITH SLEEP AND HYPNOSIS[1]

By Professor IVAN PETROVITCH PAWLOW
PETROGRAD

THE subject of this address is the highest nervous activity of the dog I have studied this activity with numerous collaborators during the last twenty years. The investigation has always been conducted on a purely physiological basis, psychological conceptions or words having never been used.

This highest nervous activity consists of analysis and synthesis of the outer and inner world. In other words, it consists of analysis and synthesis of stimulations which reach the cerebral hemispheres from without or from within. This means that it consists of connections and disconnections of different points of this part of the nervous system. Analysis and synthesis are accomplished with the aid of two processes—stimulation and inhibition.

The chief basis of all nervous activity consists of so-called reflexes or instincts, the latter being the more complex reflexes. Reflexes are the inborn connections between definite outside agencies and corresponding definite activities of the organism. This reflex activity is the function of the lower parts of the cerebral nervous system. During the life of the individual, temporary connections are formed in the cerebral hemispheres, under special conditions, between agencies and physiological activities, in accordance with the principle of signalization adopted. I term inborn reflexes "unconditioned reflexes," those individually acquired "conditioned reflexes." If the action of a previously indifferent external agent coincides a number of times with an inborn reflex, it acquires the power of producing exactly the same reaction as the unconditioned reflex. For example, food initiates a number of reactions, *i.e.*, the animal performs certain movements with regard to food and secretion of saliva and gastric juice occurs. If the feeding of the animal coincides a number of times with a certain sound, previously entirely indifferent, it evokes the same reactions as the food itself. The easiest way to gauge the intensity of this reaction is to measure the amount of the secreted saliva. A similar procedure may be applied to the formation of conditioned reflexes caused by any other agent of the outer world, as in the case of self-protection and sexual instincts. But in this discussion I will refer only to the food instinct.

[1] Abstract of a lecture delivered at the University of Chicago, July 5, 1923.

Conditioned stimuli act as signals for unconditioned reflexes; for this reason they always require correction. If the conditioned stimulus is not accompanied by the unconditioned one, the former temporarily loses its stimulating action. For instance, if, in the example already mentioned, the sound is not accompanied by feeding, it eventually loses its food reaction. But after an interval of several minutes, or in some cases, hours, this reaction spontaneously returns. In this case we are dealing with an inhibition of the reflex and not with its destruction. To take another example. If, to an established conditioned reflex, any indifferent agent is added, and this combination is not accompanied by feeding, then the conditioned stimulus used in the combination gradually loses its stimulating action. This is also a case of inhibition. The inhibition, which in this way always affects the synthetical activity, plays an important part in the analytical activity also. In the formation of a conditioned reflex the following law holds: Every agent, after becoming a conditioned stimulus, has a very generalized type, *i.e.*, the conditioned reaction is provoked not only by the specially chosen stimulus, but by any one of the same type. Making use of the inhibitory process, all these similar agents may be deprived of any stimulating action, and a very perfect differentiation of the primary action may be thereby obtained. In order to get this result it is necessary to apply repeatedly, in the absence of feeding, the agencies which had become spontaneously active, and during the same interval of time to reinforce the original conditioned stimulus, *i.e.*, to accompany it by feeding; in other words, by an unconditioned reflex. In this way the highest degree of analysis of which a given animal is capable is realized.

After this introduction I can now proceed to the main subject of my address. As the result of many preliminary guesses and tests we have arrived at the following thesis: Inhibition, ordinary sleep and hypnosis are one and the same process. This is a fundamental fact which has long attracted our attention in the course of the study of conditioned reflexes. Every conditioned stimulus, as soon as it is used alone without being accompanied by an unconditioned one, leads, early or late, to a drowsy state or to sleep. The difference between the various experiments is quantitative only. Some definite agents, used as conditioned stimuli, produce sleep in a shorter time than others. In a similar way some animals develop this response more easily than others. As a general rule, sleep is induced the quicker, the longer the conditioned stimulus acts alone without being accompanied by an unconditioned one. Experiments frequently show the following striking features: We have, for example, in our laboratory a dog which, when not fed for about

twenty hours, is always greedy for food. The conditioned stimulus, after being used during fifteen seconds by itself before the actual feeding, at first invariably produces the feeding reaction, motor and secretory. During these experiments the dog always remains wide awake. Now, if we make the interval of time of the action of the conditioned stimulus, in the absence of feeding, longer (say thirty seconds), after a few (three to five) repetitions the dog gets drowsy, and at the end falls so soundly asleep that to take food at the end of thirty seconds he has to be forcibly awakened

This circumstance may be most easily understood as follows: The isolated, concentrated stimulation of cells of the hemispheres presently leads to their exhaustion and to sleep, if not interchanged and not accompanied by the stimulation of other cells. We know that normal sleep supervenes as a result of general exhaustion of the hemispheres. In this particular instance the only point which is not quite clear concerns the manner of spread of the inactive state from the exhausted cells to those cells which had not been involved in work. It may be assumed that the exhaustion of certain cells causes the formation of some unknown substance or process, which in its turn produces an inactive state of the exhausted cells and spreads to other (fresh) cells.

In support of the sleep-inducing action of the conditioned stimuli under special conditions may be adduced a similar well-known fact, that uniform and monotonous surroundings usually predispose to sleep in persons who are not even tired.

This condition, which in the case of conditional reflexes leads to sleep, is exactly the same as that which leads to the development of inhibition. Every time that the conditioned stimulus is not accompanied by an unconditioned one, it is gradually inhibited. Further, whenever the inhibition is developed in a definite phase, sleep follows, if special precautions are not taken to prevent it. Finally, cases are constantly met with in which either inhibition or sleep may develop, or inhibition may pass into sleep, or vice versa, or both conditions are present and are added to one another. These considerations have led us to the conclusion that inhibition and sleep are identical processes.

But how is it that inhibition is a constant and essential element of the active state of the hemispheres, and sleep of a resting state? The answer does not seem to be difficult. Inhibition is partial sleep, or sleep distributed in localized parts, forced into narrow limits; true sleep is a diffused and continuous inhibition of the whole of the hemispheres. The distribution and division of inhibition, the forcing it into narrow limits, is accomplished by means of an opposing process of stimulation. The formation of points of stimulation

in the hemispheres is a reliable and constantly used method for limiting inhibition or for dispelling sleep.

The following examples may be cited: A dog is falling fast asleep when the conditioned stimulus is applied thirty seconds in advance of the feeding. In order to avoid sleep, it is now necessary to form new conditioned stimuli, using new agents to stimulate new points of the hemispheres, whilst at the same time making the intervals between the new stimuli and feeding shorter. The first stimulus, separated from its associated feeding by thirty seconds, and applied in the intervals between the newly produced stimuli, no longer causes sleep.

We can, however, differentiate the related stimuli from our original conditioned stimulus by repetition without feeding. If we do this the stimuli gradually lose their stimulating action; at the same time the animal grows drowsy and finally falls asleep. It is only when the differentiated agents are alternated with the original conditioned stimulus that the sleeping state is gradually dissipated and the pure inhibition of these differentiated agents alone remains.

A variation of this experiment may also be mentioned. With mechanical stimulation of different points of the skin, it may be often observed that the inhibition which is produced from one point is unable to affect a point which has been much more highly exercised; nor can it pass this point.

These facts imply the idea that the processes of inhibition and sleep are capable of spreading over the area of the hemispheres. This assumption can be verified by direct experiment.

The chief merit of the physiology of conditioned reflexes consists in the fact that it has undoubtedly proved that inhibitory processes have the property of spreading (irradiation).

Let us place on the skin of the animal a series of instruments, producing mechanical stimulation of the skin. Let us form the conditioned stimuli out of all these mechanical stimuli in such a way as to obtain the same quantity of saliva from each of them. Now let us differentiate a point at one end of the series. Using the procedure described we can make the corresponding stimulation inactive. This means that we produce inhibition in the corresponding point of the brain. Then by observing the effects which are produced at the active points at different intervals following stimulation at the selected initial point, we easily recognize that the inhibition from the initial point first irradiates at a definite rate over the active points and afterwards again concentrates itself at the initial point. It is a fact of great interest that this movement of the inhibitory process is very slow—it is measured in minutes. In our daily experience we encounter exactly the same fact concerning

sleep, which gradually takes possession of the hemispheres and then, after a certain period of time, leaves them. Of no less interest is the fact that the rate of irradiation of the inhibitory process varies widely in different animals. It may be ten times greater in one than in another. This is in complete accordance with the circumstance that different persons fall asleep and awake at different rates. I regard the facts mentioned as proving conclusively the identity of inhibition and sleep.

From this point of view the phenomenon of hypnosis may be easily understood. It represents one of the different steps in the process of irradiation of inhibition over the mass of the hemispheres —the partial sleep of the hemispheres. We have often observed the following striking phenomenon in the dog. We produce inhibition by any known method and give time for it to irradiate until the following definite stage is reached: A chosen conditioned stimulus still affects the secretory reaction; the saliva flows, but the animal does not take food which is offered to it. This means that inhibition has taken possession of the motor area of the hemispheres, but has not yet irradiated to other parts of them; those, for instance, which are in connection with the eyes, the ears, and so on. This is obviously analogous to a special phase of human hypnosis, when the hypnotized person hears you and understands you, but can not make any voluntary motion.

Thus the hemispheres, in an active state, show an enormous mosaic of points stimulated and inhibited (or sleeping) which are very close and mixed up with one another.

Hypnosis is inhibition spread over the usually active points in special areas of the hemispheres.

Sleep is inhibition irradiated over the whole area of active points of the hemispheres and even over some parts of the brain below the cerebral hemispheres.

But even when the inhibition is widespread there still remain certain isolated active points (so to speak, on the alert) which are capable of being stimulated. We know this from daily life; a miller is awakened by the stopping of his mill, a mother is roused by a movement of her sick child. Similar facts may be observed in dogs and may be artificially produced.

The process of inhibition is one the development of which is to a great extent dependent upon practice. This may supply the foundation for a hygiene of inhibition in both active and sleeping states.

A question of great importance is, whether the highest nervous activity—individual perfection—may be of use to the next generation, *i.e.*, whether it may be inherited. We have tried to find an

answer to this question, and have obtained certain experimental results. We established the conditioned food reflex in white mice, making use of the sound of an electric bell. With the first set of (wild) white mice it was necessary to repeat the combination of ringing the bell and feeding three hundred times in order to produce a well-established reflex. The second generation formed the same reflex after a hundred repetitions. The third generation acquired this reflex after thirty repetitions, the fourth after ten and the fifth after five only The experiments had reached this point when I left Petrograd this summer. On the basis of these results I anticipate that one of the next generations of our mice will show the food reaction on hearing the sound of the electric bell for the first time This result would be analogous to the well-known fact that a newly hatched chicken immediately tries to peck small objects or spots which it sees on the floor. If the stimulation of an eye, as in this case, leads to the food reaction, why may not the stimulation of the ear in the former case produce the same effect?

PLANTING IN THE NATIONAL FORESTS

By C. G. BATES

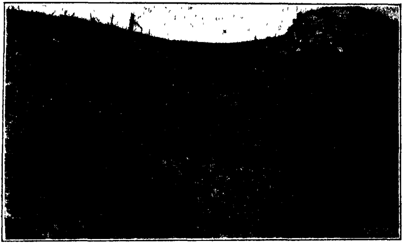
FREMONT FOREST EXPERIMENT STATION, U. S FOREST SERVICE

THE writer having been identified, if only in a modest way, with the early struggle for the forest conquest of the Nebraska sandhills, and, because of interest in this struggle, having followed the technical problems which have been encountered in other similar undertakings, may pretend to speak of the planting work on the National Forests with some authority, even though not strictly engaged in this line, but rather with forest investigations in general

If we may, only seventeen years after the beginning of such work by the Forest Service, look at the progress of planting in retrospect, there is one fact which stands out preeminently, and that is that the marked successes have almost without exception been in localities in which the soils are relatively light This is most strikingly illustrated by the barren sands of Nebraska, but is hardly less true in Michigan, Minnesota, the Pike's Peak region of Colorado and even with the planting of maritime pine in Florida The reason for these successes is not far to seek, for all the large-scale planting has been done with coniferous trees and a large proportion of it with representatives of the genus *Pinus*. Not only has it long been recognized that the pines *will grow* on light, infertile soils usually unsuitable for agriculture, but recently at the Fremont Experiment Station we have obtained direct evidence that as a general rule soils of meager fertility are much more likely to stimulate vigorous growth of the pines A complete explanation of this is not yet available, but it appears that a poorly leached soil which accumulates fertility (nutrient salts) useful to such highly developed trees as spruces also accumulates some salts which are definitely toxic to the pines. In nature the necessary leaching to prevent any dangerous accumulations of salts is usually secured through one of the following conditions:

(1) Extreme porosity of the soil.
(2) Steep slopes and free sub-drainage, as on mountains.
(3) Heavy precipitation with some drainage

Another fact which has been strikingly brought out by the National Forest planting is that many areas in which either natural seeding or artificial seed distribution by man have failed to generate forest growth may be readily reclaimed by the planting of



RUGGED MOUNTAINS OF THE PIKE'S PEAK REGION, DEVASTATED 60 YEARS AGO

the proper kind of nursery stock. So far, the cases of this kind which have been encountered may be characterized by the fact that the soils are rather loose, drying quickly at the surface, and the atmospheric conditions are also highly conducive to quick drying, with the result that, even if rains occur rather frequently, there is little chance for seeds to germinate and rarely time enough for the roots to penetrate to a safe depth. The key to the situation lies in these words "safe depth," for usually a soil which dries quickly at the surface retains well its moisture a little deeper. The success of planting on such sites, where seeding has failed, is due entirely to the fact that the roots of planted trees are at once placed at a depth where drought seldom reaches.

Another great obstacle to natural reseeding is the competition of established vegetation, such as a grass sod, and this obstacle is not so easily overcome by planting, for very often the roots of these smaller plants, already established, penetrate as deeply as can the roots of the newly planted tree. The mere mechanical act of excavating for the tree, however, destroys existing roots in a small space, and gives the tree a temporary advantage. At this stage, then, success or failure depends very much on vigor and proportion of the nursery stock. Without going into details of nursery technique, it may be said that the Forest Service has learned well the lesson of using only trees with well-developed roots and fairly small tops. It is interesting to observe that western yellow pine, the most "drought-resistant" tree of the Central Rockies, suffers particularly in planting if the nursery stock is too old or too large. There is, naturally, a limit to the amount of root that can be planted

BEAUTIFIED AND RECLAIMED BY THE PLANTING OF WESTERN YELLOW PINE, NOW 10 YEARS OLD

with economy, a maximum length of about 12 inches ordinarily. Yellow pine trees usually have only a few such roots. If, then, the top is disproportionately large, the loss of water by transpiration from it may easily exceed the intake of water by the roots. The interesting fact is that which has been demonstrated experimentally, namely, that relative to other species the yellow pine is not at all conservative of water. For trees of uniform size yellow pine will transpire more water than their associates, such as Douglas fir and spruce. Any appearance the pine may have, therefore, of being "drought-resistant" is due entirely to the fact that, as it develops naturally, it sends its roots down quickly and vigorously to the safe moisture zone of the soil.

The competition of other vegetation can only be avoided by sowing or planting before this other vegetation establishes itself, as, for example, immediately after a destructive fire. This is the natural method by which millions of acres of lodgepole pine have become established in the Rocky Mountain region, this species having no claim whatever to drought-resistance, but merely a fortunate manner of carrying its seeds through fire. This principle being well established, practically no seeding is being done on the National Forests to-day except on new burns, and for the sake of economy planting is also being restricted to areas in which competition is not keen.

The Roubaix Area in the Black Hills is one of historical interest which beautifully illustrates the principle outlined above. Broadcast seeding on this area was started in 1904 or 1905, very

THESE PLANTATIONS BORDER THE PIKE'S PEAK AUTO HIGHWAY AND FURNISH INSPIRATION TO THOUSANDS OF AMERICANS

soon after an extensive and completely destructive fire. At first the success of the yellow pine seedlings was phenomenal. Each year's seed-sowing, however, was less productive, and by 1910 the failures were almost absolute. Following this, even planting of nursery stock was attended with much difficulty.

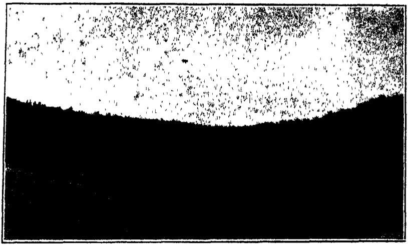
As a result of the early success of seed sowing, much similar work was done elsewhere under less favorable circumstances, a large proportion of it being wholly unsuccessful. Foresters were very much at a loss to explain these facts, since the history of the Roubaix area could not be closely correlated with any change in weather or climatic conditions, until finally it was realized that in a few years this area had gone through a complete vegetative transition, a heavy sod having been formed.

The Nebraska sandhill planting and most of its technical problems having been fully discussed in a government publication, it it not my intention to mention it further in this connection, but rather in a more sentimental way as the most striking success in technical forestry which may be credited to the Forest Service. The writer having known these sandhills, in childhood, in their most desolate and unattractive condition when being heavily overgrazed, can perhaps appreciate better than the average person the miracle that has been wrought by the perseverance of a handful of pioneering foresters. It will do no harm to pay tribute here to Scott, Mast, Bessey, Pierce, Johnson and Higgins as the outstanding figures whose personal labors have accomplished this remarkable thing. It is indeed unfortunate that the locality of this work is

HERE ARE NEBRASKA SANDHILLS IN AN UGLY MOOD, GRAZED TOO HEAVILY

not much visited by Americans in general. It is, however, still possible for any one traveling to the Northwest, via the C. B. & Q. railway, to obtain a distinct impression of the accomplishment, if not a knowledge of its details, for soon after leaving Broken Bow, Nebraska, the train enters the sandhill region, and on both sides of Halsey there is opportunity to observe the stark nakedness of the country. If one has come from the West, after riding through the flat plateau region around Alliance, and then three or four hours of sandhill landscape, he will be fairly smitten by the contrast with the several miles of pine-clad hills which near Halsey lie to the south of the railroad and the Loup River. One must see the pines against snow to obtain a clear detailed picture of their development, and to realize that their presence has indeed recreated the region, but even at midsummer their dark green is a decided contrast to the pale vegetation and the glistening sand of the hills. On entering one of the older plantations one finds himself surrounded by trees now at least twenty feet high, sending their tips skyward at an altogether surprising rate. Surely there was divine inspiration given to the man who first conceived the possibility of this, the late beloved botanist, Charles E. Bessey.

Planting on the National Forests having now become more or less stabilized, being limited in scope by the funds available, the time has arrived when a study may be made of such questions of technique as affect both the cost, the immediate success and the ultimate productivity of the work. Of these considerations, the last deserves most consideration, because the factors involved are

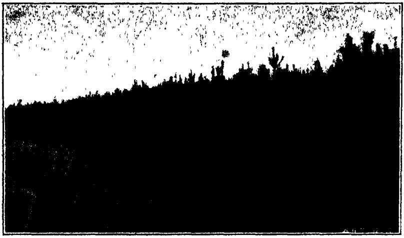


AND HERE A FEAST FOR HUMAN EYES—JACK PINE PLANTED IN 1911

comparatively obscure. Some of the factors involved in the ultimate value of plantations, which may at this stage appear very promising, are method of planting, species used and variety or geographic form of the species.

Those familiar with forestry literature will recall that for years a controversy has raged in Europe as to whether planted trees develop normally, that is, as soundly and as well as trees coming directly from the seed. It may be said that as yet in the United States we have only an echo of this controversy, no observed cases of maldevelopment having been reported from our plantations. Our analysis of the matter is merely this, that when trees with a considerable mass of roots are planted, there is a chance that all the existing roots may be placed in the soil in a ropelike mass, instead of being spread as a network through the soil. There is, then, some danger that there will be no spreading of the roots immediately below the surface, bracing the tree to the fullest extent, and that as a result the tree may show a lack of wind-firmness. There is also danger that the roots so placed in contact may, as they develop, graft together, adding a chance for the development of decay. These considerations are with us still entirely theoretical, but they must be borne in mind. Particularly in the sandhill planting, where the trees are set in slits, observation on existing trees may develop the need for a different planting practice.

With the exception of western yellow pine, all the species planted in the Nebraska sandhills have been exotics to the region, and even this species can hardly be called "native." Jack pine



A SUCCESSFUL PLANTATION OF SCOTCH PINE, DATING BACK TO 1910. PROBABLY THE RIGA VARIETY

from the Lake States region has found great favor, because, like most weeds, it grows very vigorously in youth, but of course, it has very limited possibilities for development in size. Now that the plantations are attaining some age, it is interesting to note that two European species, which have not particularly recommended themselves because of relative difficulty in the initial stages, are making excellent showing. These are Austrian pine and Scotch pine, the successful plantation of the latter being undoubtedly of the Riga or northern variety.

Little or no success with exotics in other national forest plantings can be mentioned, so that plans have gradually settled down to consideration only of the native, well-tried species. This is partly because in the Rocky Mountain region, generally speaking, the temperatures are low and the growing season short, and partly because the prevailingly dry atmosphere calls for certain adaptations, for the conservation of water, which the exotics as a rule have not developed. Thus, a majority of exotics tested have survived the first summer after planting, and even a succeeding winter if fully covered by snow, but the foliage is quickly burned when exposed to the dry winter winds. Again, Austrian pine in the foothills and Scotch pine at middle elevations promise to be partially successful, but not in a degree to warrant the hope that the native types of timber may be improved upon.

Finally we come to the question of varieties. It has taken many years of experience and considerable educational activity on the part of ecologists to bring foresters to a realization that climatic

conditions have a most decided effect on the character of the native vegetation, that climatic conditions may vary widely over the range of a given species, and in very essential respects, and that in consequence, by adaptations to these different conditions, a given species may develop climatic varieties which from a practical standpoint are just as different as though they comprised distinct species. Western yellow pine furnishes as good an example of this as any, having a very wide range. Forms of western yellow pine from California and Oregon have been incapable of surviving the winter conditions in the Central Rocky Mountains, even in a well-sheltered nursery. On bringing together the Montana, Colorado and Arizona forms of this species, in Colorado, differences are plainly visible: Both the northern and southern forms are much less adapted to withstand severe exposures than the indigenous form, and laboratory tests show that the three varieties give quite different reactions to light and moisture It is, then, perfectly apparent that we have in the national forests the same problems of seed supply which have for years vexed European foresters, and probably even more acute problems because of more varied climatic conditions. This and the coordinate matter of individual selection and breeding are problems which deserve the most careful consideration by research workers, and meanwhile should give rise to extreme caution on the part of practitioners.

Forest planting on the national forests has undoubtedly had its most trying experiences and is mainly beyond the experimental stage. Entirely satisfactory progress is being made on the larger projects in which activity is centered. The present need is for expansion in the rate of planting in order that several million acres of barren land may quickly be placed on a productive basis.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

THE SHUT-EYE SKEPTIC

THE history of science follows the plan of the catechism. Each new topic begins with a question. "First catch your hare Then take it apart," was the rule of the old cook book. "First catch your fact. Then take it apart," is the rule of scientific procedure. Whenever a scientist is called upon to explain something strange he asks "Is it so?" before attempting to account for it. He knows the natural credulity of man so well that he is very reluctant to accept on anybody's say-so an unverified statement.

This is what is known as "scientific skepticism," which is quite the proper attitude of mind if taken in its primary meaning. For the skeptic is, by derivation of the term, the man who sees, who looks into things, who keeps his eyes open. But on account of the natural tendency of words and men to deteriorate the skeptic may in the course of time come to mean one who shuts his eyes and refuses to see what is plain to other folks. For that reason science has had sometimes to retrace its steps and pick up something that it had overlooked or deliberately rejected.

An amusing instance of this is found in the history of meteorites. The ancients saw nothing incredible in the falling of stones from heaven. Heaven was to them only a sort of upper story of the earth. It was a roof to the world, just high enough to clear the mountain tops and quite as substantial. That there were chinks in the blue-painted ceiling could be seen at night when light leaked through, and it was not surprising that occasionally a stone got knocked off the battlements like a tile from a roof. The gods, especially Jupiter and Thor, threw stones and thunder-bolts at one another in their upstairs quarrels, and sometimes missed their aim, like mortals, and then these missiles fell to the earth

So we find learned men, like Livy, Pliny and Plutarch, recording the fall of meteorites, together with other information, true and false, in the field of "meteorology." But when we come down to the "Era of Enlightenment" of the eighteenth century we find arising a skeptical spirit. The old myths and superstitions were ruthlessly swept away and with this mass of rubbish a few grains of truth. The telescope had knocked the roof off the world and removed the stars to unmeasurable distance. It was known that above the earth and below it was empty space. There was no loft aloft in which stones could be stored. The museums which had preserved stones said to have fallen from heaven took them out of the exhibitior cases and threw them away lest the museum should be laughed at for preserving such relics of superstition.

Nevertheless stones continued to fall. But rarely and in remote places so they could be disposed of by denial. In 1751 a meteorite was reported to have fallen in Agram. But Agram was inhabited by southern Slavs who could not be expected to know any better. In an enlightened land like Germany they knew better, at least they had learned better by 1790, when Professor Stuetz wrote "that iron should fall from heaven might in 1751 have been believed even in Germany by sensible people on account

CHARLES PROTEUS STEINMETZ

At his desk in the laboratories of the General Electric Company. His death at the age of fifty-eight years is a serious loss to electrical engineering

of the then prevailing ignorance of natural history and physics, but in our time it would be impossible for such fables to find credence."

But in that same year, 1790, a meteorite fell in Juillac, France. It came blazing through the sky and exploded with such a bang that everybody there knew about it and fragments could be picked up. The mayor of the town sent in to the French Academy of Sciences a report of it attested by three hundred witnesses.

What do you suppose that learned body did with the document? You might know if you had had any experience with such bodies. The matter was referred to a committee.

But the referee, M. Bertholon, could see in it nothing but a deplorable example of the persistence of popular credulity. In his report to the academy he expressed his pity for the community which had a mayor so stupid as to believe such stories. "Is it not sad," he said, "to see a whole municipality attesting in a formal protocol to a popular superstition? The philosophical reader can find nothing to say when he sees this authenticated testimony to an obviously false statement, a physically impossible phenomenon." The savant, A. Deluc, expressed the prevailing attitude more emphatically when he declared that if such a stone should fall at his feet he would have to admit that he had seen it but he could never believe it.

But what was then so impossible that a wise man would refuse to believe his own eyes is now universally accepted. The museums again take pride in exhibiting meteorites. The biggest known, a mass of meteoric iron weighing more than thirty-seven tons, brought by Peary from Greenland, may be seen at the entrance of the American Museum of Natural History at New York. And it is estimated that 100,000 tons of meteoric dust and stones fall annually upon the earth. Every fall and find is eagerly examined to see if it brings us any news of other worlds than ours. But of the thirty elements found in meteorites there is none that was not already known on earth, though the combinations and proportions are somewhat different. These visitors evidently come from where water and air are limited or lacking, but otherwise they are made of much the same stuff as our own earth.

BACTERIA RUN ENGINES

In India, where the elephant was first tamed for power, bacteria are now being cultivated for the same purpose. This descent in the course of centuries from the largest to the littlest of living creatures is likely to prove a gain in efficiency, for the microbe will feed on sawdust and does not even need air to breathe.

The rodlet bacteria that are being colonized for the running of dynamos thrive best in dark air-tight tanks of sewer sludge and sawdust kept at a temperature of 95 degrees Fahrenheit. Under these conditions they multiply amazingly and set about converting the septic slush into harmless and indeed useful compounds. One of the products of their activity is acetic acid which might be used for vinegar—if you did not know where it came from. The fermentation of the cellulose of the woody stuff gives also gases, chiefly carbon dioxide and methane. The former could be used for charging soda-water if it were worth while. The methane is, however, of real value since it is the best of gases for motor fuel or for heating or with a Welsbach mantle for lighting. Natural gas from wells is about nine tenths methane.

PROFESSOR IVAN PETROVITCH PAWLOW

With his son who accompanied him on his recent visit to the United States. The photograph was taken by Julian P. Scott

The method of making methane by fermentation with the aid of the airless bacteria is not new. In fact, it was first found bubbling up from the decaying vegetable matter in stagnant pools and was formerly called "marsh-gas." If you look in one of the old text-books of chemistry, in the days when they had space for such interesting little items, you will find a picture of a boy collecting the bubbles of the escaping gas with an inverted funnel and lighting it. But our grandfathers, being impractical and imprudent creatures, although fortunately for us curious in nature's ways, thought of marsh gas only as a plaything and never dreamed of setting it to work as we do now-a-days.

In the Ruhr region of Germany a large municipal sewage plant has been constructed so as to save the gases given off from the fermentation of the sludge by putting concrete hoods over the digestion tanks. This gas contains from 65 to 90 per cent. of methane and sometimes hydrogen up to ten per cent. The gas is better than the ordinary city gas. In fact, it has about twice the heating value per cubic foot of that furnished by the gas plant of Essen. From the Ruhr experience it is estimated that by employing the proper bacteria a city of 100,000 inhabitants could get eleven million cubic feet of combustible gas a year out of its sewage sludge.

A Dutch manufacturer of strawboard was much annoyed when the government ordered that the waste liquor from the wood pulp should not be allowed to flow into the river, but should be run into storage tanks for settling and filtration. It seemed a bother and expense to the manufacturer, but he found that if the tank were inoculated with the proper bacteria and kept warm and closed a gas could be collected from it of twice the volume of the liquid. This gas contained from 70 to 77 per cent of methane, the rest being carbon dioxide The methane was run into gas-holders and used in internal-combustion engines for running dynamos that furnished light and power for the works, and the surplus gas was sold to the local gas works which mixed it with 25 per cent. of coal gas and used it for the town. It has been found possible in India to get by fermenting banana stems and skins a gas containing 81 per cent. of methane and 14 per cent. hydrogen.

It has often happened that the government, in suppressing a public nuisance, has forced a factory to make a profit out of a waste product. It has come to be a proverb in engineering circles that "Wherever there's a nuisance there's a waste and wherever there's a waste there's wealth."

A PLEA FOR A SCIENTIFIC THEOLOGY

THE editor of "Christian Education" asked me to point out the defects of theological seminaries. Of course I complied. It is fun to find fault with anything when you are not to be held responsible for making it better.

I never took a course in a theological seminary, but one can judge something of the workings of a factory from its output. And I remembered what Dr. Oliver Wendell Holmes replied when the preachers asserted that he had no right to meddle with questions of theology since he had had no training in that field. He said—if I do remember it—that after he had listened to medical lectures for three years he was made doctor of medicine with the right to practice and teach, but that after he had listened to theological lectures for thirty years he was not considered competent to express an opinion on the subject.

Theology is a free-for-all field from which not even professionals are barred. And if the professionals do not take advantage of the new opportunities that science is opening to them, it is likely to pass mostly into the hands of amateurs.

So possibly the readers of THE SCIENTIFIC MONTHLY, who mostly belong to the amateur class of theologians, may like to see my criticism of present-day theological graduates. It was:

"I do not know enough about the curricula of theological schools to suggest any improvements. Their graduates are good fellows, energetic, earnest, ambitious and liberal-minded. They seem to be smartly up-to-date in all respects but one, and that is theology. Most of them do not seem to have any or any interest in any. By theology I do not mean a particular system of dogmatic doctrine but rather the habit of thinking about the fundamentals of faith and reason, about the metaphysics that lie at the base of physics, the psychology that controls character and motivisation, the personal philosophy that is the compass of conduct. It is the schools of science, not the schools of theology, that are turning out the thinkers in such fields.

"We are in the midst of the greatest revolution of thought that the world has ever seen, the Einstein theory of relativity, the Planck theory of quanta, the chromosome theory of heredity, the hormone theory of temperament, the new knowledge of the constitution of the universe and of the workings of the human mind, these ideas will influence the philosophy, theology, religion and morals of the future as much as did the Copernican theory in the sixteenth century and the Darwinian theory in the nineteenth. Such questions would have aroused the keenest interest in the minds of men like Edwards, Berkeley, Calvin, Aquinas or Paul. A student in engineering or biology will sit up half the night discussing these theories, but your modern theological graduate is bored by them. He has learned how to give the glad hand to the strangers at the church door and can teach boy scouts how they should salute the flag—things that a pump-handle or drill-sergeant could do as well—but he is not qualified to lead his people through the mazes of modern thought. Since sermons have become sociological instead of philosophical serious minded people are going elsewhere to get their metaphysics and often getting a poor brand of it from unqualified dispensers. When a young preacher does touch upon such topics —which is fortunately seldom—he is apt to reveal a materialistic conception of matter that sounds amusingly antiquated to his scientific hearers.

"It might be said that the present situation is an improvement over the old since the clergy, as a rule, no longer fight such new theories as they did Copernicanism and Darwinism. But I am not sure of that. A wrong-headed hostility is a better sign than entire indifference, for the latter looks as though the church were outside the current of modern thought. If the church is to be anything more than the Boosters' Club of Zenith City there has got to be some hard thinking done by those at the head of it during the next twenty years. Somebody has got to seize hold of these new conceptions and point out their moral applications. Otherwise somebody else will make immoral applications of them.

"Unless the preacher gets accustomed to deep diving while he is young he is apt to swim shallower and shallower as he gets on in life. Unless he has thought things through for himself he will be at the mercy of every passing fad that blows. Theological schools ought to teach theology."

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